instruction manual

CALIBRATION LAB.

Model 5210 Portable EPUT® Meter

Beckman® / *Berkeley Division*

INSTRUCTION MANUAL

MODEL 5210
EPUT® METER

Lot No. _____
Serial No. 104

NOTE

IF MODEL NUMBER IS FOLLOWED BY AN INKED-IN LETTER, THE INSTRUMENT THIS MANUAL ACCOMPANIES HAS BEEN MODIFIED IF SO SEE THE SECTION ON MODIFICATIONS BEFORE READING FURTHER.

Beckman
Berkeley Division
2200 Wright Avenue, Richmond 3, California
a division of Beckman Instruments, Inc.

July 2 1957

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(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

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Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

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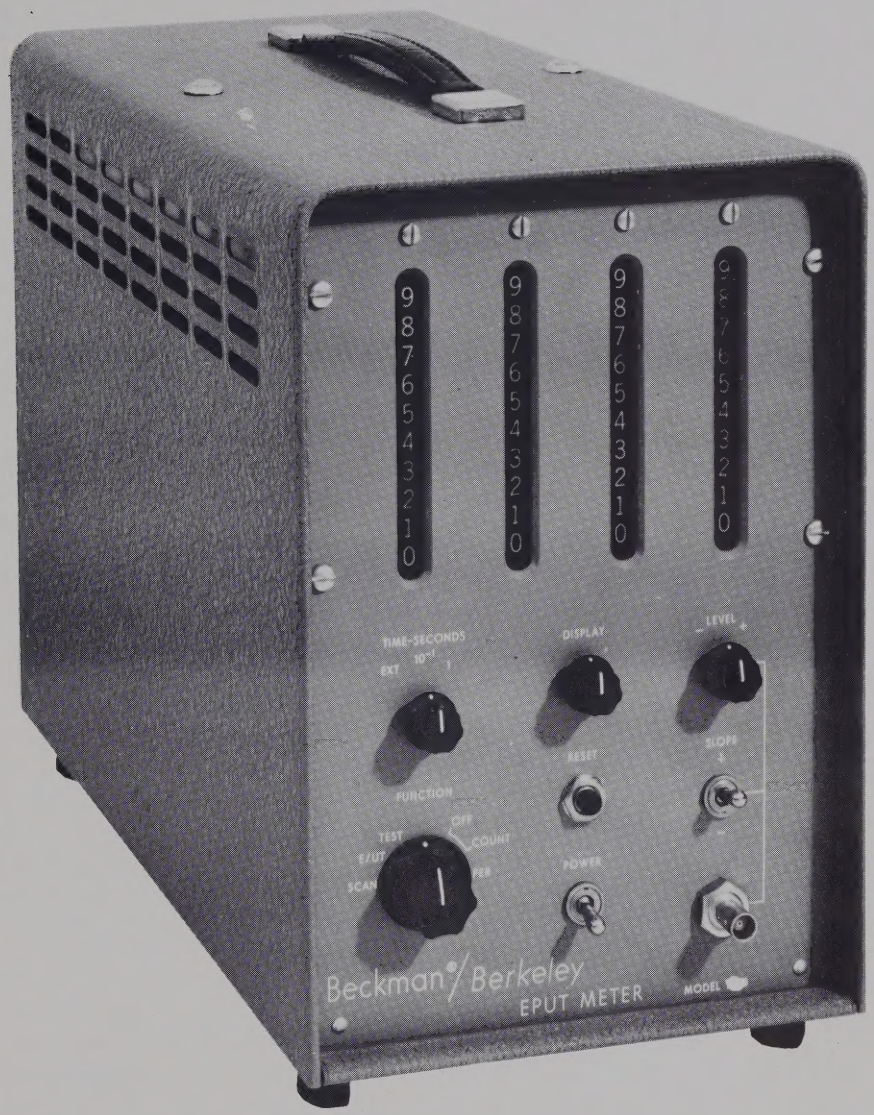
TIME-SECONDS
EXT
DISPLAY
LEVEL
RESET
SLOPE
FUNCTION
TEST
E/US
SCAN
OFF
COUNT
POWER
MODEL
Beckman Berkeley
EPUT METER

Model 5210

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INTRODUCTION

GENERAL DESCRIPTION

This instrument is designed primarily to count events occurring at rates up to 100,000 per second during a precise time interval. The instrument consists of a time base generator, an input pulse-forming channel, an electronic gate and a chain of decimal counting units. The events counted may be any optical, mechanical or electrical occurences which can be represented by voltage changes at the input terminal. Each input voltage excursion causes the pulse-forming channel to generate a fast pulse. If the input is a cyclical signal, one pulse will be generated for each cycle. These pulses are applied to the electronic gate, which is open during a precise period established by the time base generator. Pulses emerging from the gate while it is open are counted by the decimal counting units, which also indicate the accumulated score. The count is accurate to ± one event ± the frequency error of the 60cps line on which the instrument is operated.

The count score appears in the form of illuminated decimal digits on the front panel. This display may be retained from the end of the counting period until the operator resets the instrument to zero by pressing a front-panel button, or the instrument may be adjusted to reset automatically after a predetermined display period of from .05 to 5 seconds.

While not primarily designed for this purpose, the instrument will also measure the time interval separating events. Used in this way, clock pulses, triggered by a line-frequency signal or some external signal, are let through the gate and counted during an interval controlled by a signal at the input jack. This is a convenient way to measure the period of signal whose frequency is so low that counting cycles would be excessively time-consuming.

FUNCTIONS

1. Measures frequency or counts events-per-unit-time over a maximum automatic time interval of 1 second with a manual extension beyond 1 second for extreme accuracy.
2. Measures period of a wave or the width of a pulse.
3. Counts events over a manually controlled time interval.
4. Makes self-check on accuracy of clock signals and Decimal Counting Units.
5. Performs any of the above functions with an external frequency substituted for the internal 60 cps line frequency.

SPECIFICATIONS

Events-per-unit-time (Frequency) Measurements

Frequency Range:

d-c to 100Kcs

Gate Times:

One tenth second and one second with manual extension beyond one second.

Accuracy:

± one count ± accuracy of line frequency.

Period Measurements

Frequency Range:

d-c to 10kcs

Time Units in which Measured:

Seconds, tenths of a second and sixtieths of a second.

Input Characteristics

Frequency Range:

d-c to 100kc

Input Impedance:

1 megohm in parallel with approx. 20$\mu\mu$f.

Input Sensitivity:

250mv rms, 0.7 volts peak-to-peak

Trigger Voltage Level:

Adjustable from -5 to +5 volts

Trigger Slope:

Positive-going or negative-going

Characteristics of Internal Time Base

Clock Pulse Interval:

One second, one tenth of a second and one sixtieth of a second. Provision is made for generating other intervals using an external frequency standard.

Characteristics of Counting Circuits

Count Capacity:

Four digits (9,999 counts)

Type of Display:

Decimal digits

Pulse Resolution:

5 μseconds

Reset to zero count:

Automatic or manual.

Count Display Time:

Continuously variable from .05 to 5 secs under automatic reset. As long as desired under manual reset.

Power Requirements

115 volts a-c ±10%, 50 to 60 cps, approx. 115 watts. On special order may be wired to operate on 105 volts ±10% or 125 volts ±10%.

Dimensions

12" high, 8" wide, 14" deep.

Shipping Weight

Approx. 30 pounds.

Other Features

Possesses an auxiliary jack for introducing another frequency to take the place of the line frequency.

Will make self-check of frequency dividers and decimal counting units.

APPLICATIONS

The portability of this instrument makes it an ideal choice for either laboratory or industrial application. For the laboratory it offers a means of measuring frequency or time to a sufficient accuracy for most routine tasks. To industry it offers the ability to stand hard use coupled with sufficient accuracy for most installations. Bright, easy-to-read numerals on the panel reduce eye fatigue. Furthermore, operation can be quickly learned by anyone without technical training.

A partial list of the applications includes:

Tachometry
Events Counting
Flow Measurements
Frequency Measurements

Berkeley Data File No. 111 has been prepared to acquaint you with some of the interesting and unique applications of this instrument. Free copies may be obtained from any Berkeley representative or from the factory. Write for: Data File 111 -- How to Make Frequency Measurements

The versatility of the instrument can be fully utilized only when it is equipped with the proper accessories. Numerous transducers such as the Model 453 photocell with 454 light source and magnetic tachometers Models 461, 465 and 466 are available at Berkeley.

The Model 1452 Digital Recorder, designed for use with modification P of this instrument, converts count information into a printed record. The unit prints the count accumulated by the counter during each counting period. The printed count appears sequentially in Arabic numerals on a standard adding machine tape. This recorder is ideal for making long term stability checks, recording transients, monitoring, or for making a permanent printed record in control or measuring systems.

The Model 5914 In-line Indicator, also designed for use with modification P, presents the count reading in large, bright red digits on a single horizontal line. The digits are about 1-1/4" high and lie in the same vertical plane; consequently, the indicator may be read from across a room and at nearly any angle to its face. The Model 5914 recives count information from a 40-pin socket at the rear of the counter and need only be plugged into this socket and connected to line power to operate.

OPERATION

INSTALLING AND APPLYING POWER

The instrument will operate in nearly any convenient location. Simply plug the power cord in a source at 115-volt a-c power and turn on the power switch.

The neon bulbs behind the lucite panels should light. Be sure the FAN switch at the rear of the instrument is ON; otherwise the unit may overheat.

When shipped, the instrument is wired to operate off 115 volts ±10%; however, the main power transformer has taps on the primary winding to which the line may be connected for operation on 105 volts ±10% and 125 volts ±10%. For details, see "Schematic Diagram, Time Base Generator and Power Supply".

BASIC TYPES OF MEASUREMENT POSSIBLE

The counter will make three types of measurements aside from simple counting.

1. It will count the number of events occurring during a precise time interval. This is known as Events-Per-Unit-Time or E/UT Operation. Frequency measurements are made in this way. The SCAN function is a variation of this operation.
2. It will measure the time interval between two events represented on the same input channel, this is known as PERIOD Operation.

If the events mentioned above are not initially voltage changes, appropriate transducers are used to produce voltage changes representing the evnets at the counter inputs. Two input trigger channels within the counter convert the voltage changes they receive into sharp pulses. A time base generator in the instrument produces similar pulses separated by a precise time interval. Besides these three pulse sources, the counter contains an electronic gate and a chain of decimal counting units. The DCU's count and indicate the number of pulses which pass through the gate between a start pulse which opens it and a stop pulse which closes it.

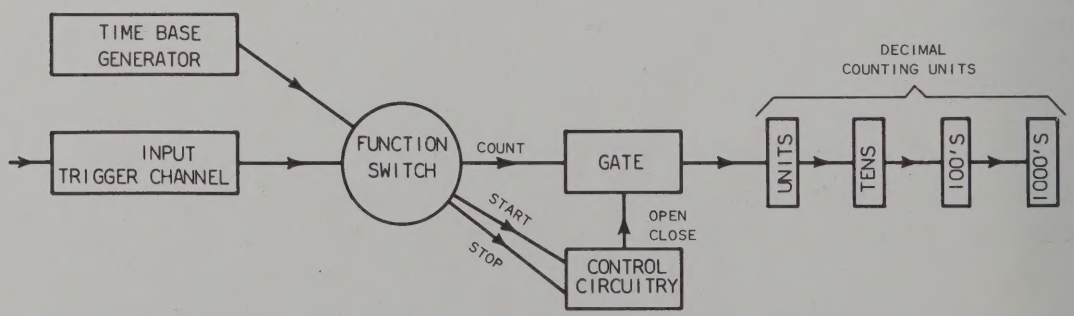


FIGURE 1. SIGNAL PATHS BETWEEN MAJOR COMPONENTS

The FUNCTION switch determines the type of measurement made by selecting the pulse source which provides each of the three signals -- pulses to be counted, the start pulse, and the stop pulse.

1. Under E/UT Operation, the input channel provides pulses which are counted over the known time interval between start and stop pulses from the time base generator. With the proper placement of a decimal point, the lighted DCU's indicate events or cycles per second.
2. Under PERIOD Operation, pulses of known frequency from the time base generator are counted over an unknown interval between start and stop pulses from the input channel.

OPERATING CONTROLS AND CONNECTORS

POWER Switch

Turns line power on and off.

FAN Switch

Located at the rear of instrument. Place at ON to energize fan unless instrument is out of cabinet.

FUNCTION Switch

Interconnects major components to perform the operation indicated. Used to manually control COUNT and SCAN operations. See figures 2 thru 5 to learn how components are connected at each position.

TIME-SECONDS Switch

Selects counting time interval for events-per-unit-time and TEST measurements and unit of time measurement for PERIOD measurements For example, with this switch at 10^{-1} and FUNCTION switch at E/UT the gate will be open to permit counting for precisely one-tenth of a second. With this switch at EXT and the FUNCTION switch at PERIOD, the reading will appear in sixtieths of a second.

Input Jack

A front-panel jack for coupling a signal to the input trigger channel.

LEVEL Control

Selects the instantaneous voltage at which a signal at the input jack triggers a pulse. By rotating the control, this voltage may be set anywhere between -5 and +5 volts. See "Input Adjustments".

SLOPE Switch

Selects the slope of the input voltage waveform which triggers the pulse used to operate succeeding circuitry. At "+" the pulse is triggered by a positive-going excursion; at "-" by a negative-going excursion.

DISPLAY Time Control

Determines how long the instrument holds a reading before resetting and beginning another count. When this control is turned clockwise until a switch clicks audibly, the instrument will hold a reading until the manual RESET button is depressed.

Manual RESET Button

Removes the previous reading and readies the instrument to begin another counting period.

INT-EXT TIME BASE Switch and Connector

These are located at the rear of the instrument. Under ordinary operation, the switch is placed at INT. In this case the line power supplies a 60cps signal which is divided to obtain clock pulses. With the switch at EXT, the internal oscillator is disconnected from the dividing chain and the operator may inject a signal at the coaxial connector beneath the switch to supply clock pulses for a time measurement. See " PERIOD OPERATION".

TESTING FOR PROPER OPERATION

At the TEST position of the FUNCTION switch, the instrument counts 60cps pulses from the shaper during the time interval separating successive clock pulses. The component parts are connected as diagrammed in figure 2. Before testing, allow the instrument to warm up a few minutes, then proceed as follows:

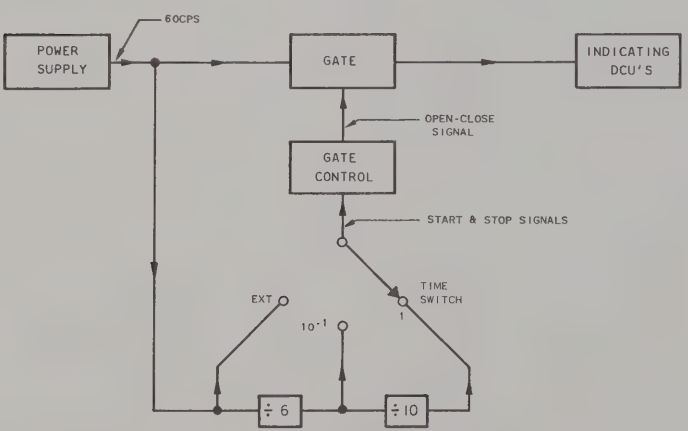


FIGURE 2. TEST OPERATION

1. Place the FUNCTION switch at TEST.
2. Adjust the DISPLAY time control to a point near the extreme counterclockwise position to obtain a short display time and automatic operation.
3. Place the TIME-SECONDS switch at 10^{-1}. The count display should be "0006" . Move the switch to "1", where the display should be "0060".

Correct readings indicate that the time base dividers are scaling correctly and that the DCU's are counting properly. An incorrect reading probably means that the divider supplying clock pulses is dividing by the wrong number. In this case, adjust the dividers as directed under "Routine Maintenance".

GENERAL PROCEDURE FOR MAKING MEASUREMENTS

This procedure may be divided into three steps: First, selecting the proper mode of operation to make the measurement desired. There are four modes of operation corresponding to four positions of the FUNCTION switch: COUNT, E/UT, SCAN, and PERIOD. The four modes differ primarily in the source of pulses counted by the DCU's and the signal used to open and close the gate. Each mode is described separately below.

Second, coupling an appropriate signal to the input channel and adjusting it to produce desired output pulses. Input requirements and adjustment are described under "Input Adjustments".

Third, following the operating procedure for the selected mode of operation.

COUNT Operation

The instrument will count pulses from the input channel as long as the FUNCTION switch is at COUNT position. The major components are connected as shown in figure 3. Counting can be manually controlled as follows:

1. Connect a signal to the front-panel input jack. (See "Input Adjustments".)
2. Turn the FUNCTION switch to OFF.
3. Depress manual RESET button.
4. Twist FUNCTION switch to COUNT to begin counting.
5. Twist FUNCTION switch to OFF to halt counting.

FIGURE 3. COUNT OPERATION

E/UT (Events Per Unit Time) Operation

At the E/UT position of the FUNCTION switch, the unit counts cycles of the input signal between start and stop signals separated by a precise time interval. This setting may be used to measure the frequency of a signal or the number of events occurring within a selected time interval. The major components are connected as diagrammed in figure 4.

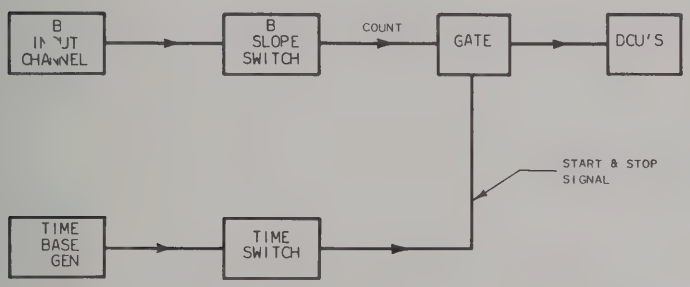


FIGURE 4. E/UT OPERATION

To make a measurement, proceed as follows:

1. Connect a signal to the front-panel input jack. (See "INPUT ADJUSTMENTS".)
2. Rotate the FUNCTION switch to the E/UT position. In this position the SLOPE switch determines the polarity of the voltage excursion which triggers count pulses. It may be at either position.
3. Set the TIME switch at the time interval over which events are to be counted.
4. Adjust the DISPLAY time control to a position at which the count on the lighted DCU's may be read conveniently.

SCAN Operation

This is a variation of E/UT operation with the object of extending the counting period beyond the maximum automatic interval of one second. The interval during which events are counted may be extended to any multiple of the one-second counting period. Consider the total counting interval desired as N seconds. Then proceed as follows:

1. Connect a signal to the input jack. (See "INPUT ADJUSTMENTS".)
2. Turn DISPLAY TIME control fully clockwise.
3. Place FUNCTION switch at E/UT.
4. Turn the TIME switch to "1" to obtain a one-second automatic counting period.
5. Press the RESET button. Within one second the instrument will begin a normal counting period.
6. Before the end of the one-second period, turn the FUNCTION switch to the SCAN position and begin timing N minus 1 seconds with a stopwatch.
7. At the end of N minus 1 seconds, turn the FUNCTION switch back to E/UT.
8. When the instrument stops counting, read the count.

PERIOD Operation

At the PER position of the FUNCTION switch, the unit measures the time interval between consecutive voltage excursions through a selected level at the input jack. This setting may be used to measure the period of a wave. The major components are connected as in figure 5.

To make a measurement, proceed as follows:

1. Connect the wave or pulse source to the input jack. (See "INPUT ADJUSTMENTS".)

2. Rotate the FUNCTION switch to PERIOD. At this position the SLOPE switch selects the polarity of the voltage excursion which begins and ends the timing period.

3. The instrument generates clock pulse frequencies of 60 cps, 10 cps and 1 cps. The unit of time measurement is a sixtieth of a second with the TIME switch at "EXT"; a tenth of a second at "10^{-1}" and one second at "1". Since even the smallest unit, a sixtieth of a second, does not permit a short time interval to be measured precisely, provision has been made to generate a higher clock pulse frequency by triggering pulses with an external signal rather than with the line frequency signal. To do this couple an external signal source to the EXT TIME BASE jack at the rear of the instrument and place the associated switch at EXT. Signal frequency may range from 60cps to 10Kcs. Required amplitude declines linearly from 20v rms at 60 cps to 8v rms at 10Kcs. Clock pulses of the injected frequency will then be counted during the PERIOD operation if the TIME switch is at EXT. However, the frequency dividers will not operate, unless the applied frequency lies between 50 and 100cps; therefore, positions 10^{-1} and 1 on the TIME switch will usually be useless. To use these positions for an E/UT measurement, simply return the rear-panel TIME BASE switch to INT.

4. Adjust the DISPLAY time control to a position at which the count on the lighted DCU's may be read conveniently.

5. To obtain a reading in seconds, multiply the count on the DCU's by the factor to which the TIME switch is set.

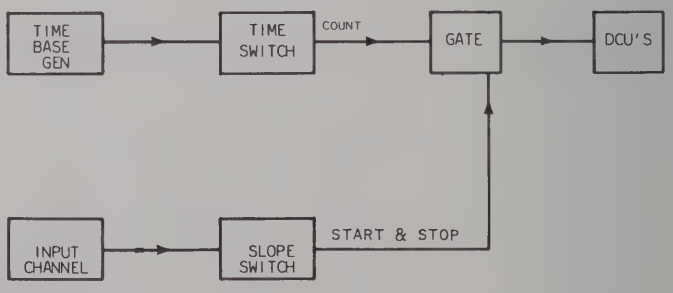


FIGURE 5. PERIOD OPERATION

INPUT ADJUSTMENTS

Input Requirements. Specified input sensitivity is 250mv rms (0.7v peak-to-peak). Actual sensitivity of a typical unit is better than this, averaging about 150mv rms (0.4v peak-to-peak). The impedance at the INPUT jack is 1 megohm in parallel with approx. 20$\mu\mu$f. This impedance may be reduced to match the source or to avoid capacitive pickup by attaching a "T" connector to the jack and adding resistors or capacitors in parallel.

A Routine Adjustment Procedure. In the common case in which the input is a cyclical signal and when the object is merely to generate one pulse for each cycle without regard for the precise time at which a pulse occurs, the LEVEL control may be set as follows:

1. Couple the signal to the input jack.
2. Place the FUNCTION switch at COUNT and press the RESET button.
3. Rotate the LEVEL control slowly from one extreme to the other. Notice that the instrument will count steadily over a certain arc of LEVEL control positions. Position the control at the center of the arc over which counting occurs. If counting occurs over the entire range of adjustment, position the control midway between extreme positions.

Effect of Input Controls. When making time measurements using the PERIOD function, the precise time at which a pulse is triggered may be critical. The trigger time is influenced by input amplitude, noise and the position of the LEVEL and SLOPE controls.

Figure 6 is a block diagram of an input trigger channel. Figure 7 shows how the varying voltage of an input signal triggers channel output pulses. A pulse is produced each time the instantaneous voltage of the signal passes through the "positive-going trigger voltage" starting from a value more negative than the "negative-going trigger voltage". Another pulse is produced each time the instantaneous voltage passes through the "negative-going trigger voltage" starting from a value more positive than the "positive-going trigger voltage". When the SLOPE switch is at "+", only pulses triggered by positive-going voltage excursions affect the secceeding circuitry. With the SLOPE switch at "-", only pulses triggered by negative-going excursions are effective.

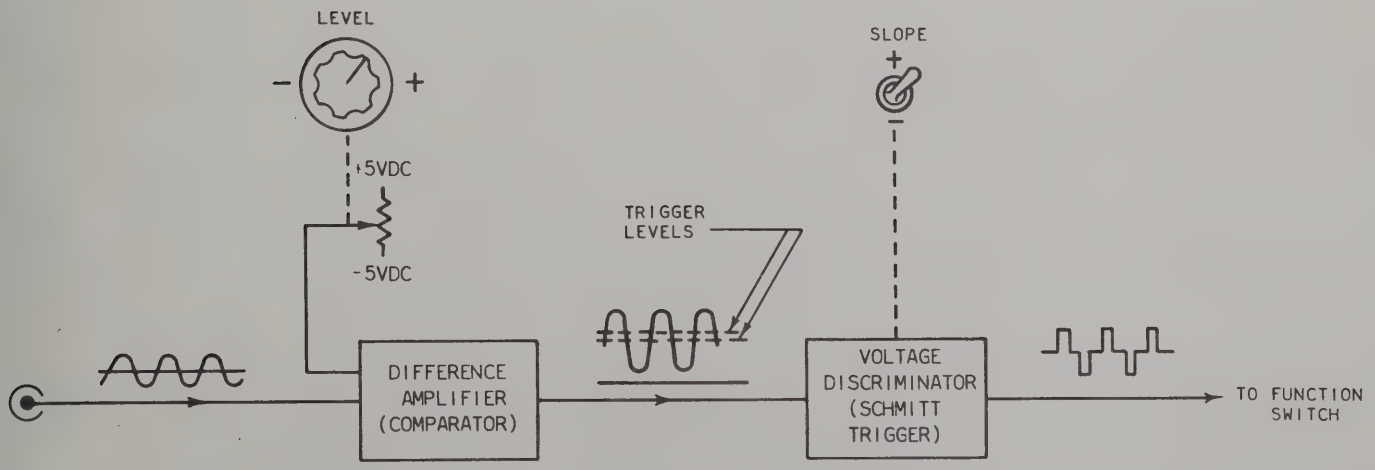


FIGURE 6. BLOCK DIAGRAM OF INPUT CHANNEL

The two trigger voltage levels)positive-going and negative-going) are always separated by 0.4 volts, the effective hysterisis. Because a voltage excursion must travel through both levels to trigger a pulse, the sensitivity of the channel to the signal is 0.4 volts peak-to-peak.

The trigger voltage levels of either input channel may be raised or lowered simultaneously (maintaining 0.4 -volt separation) when the level control for that channel is varied. This control will vary the levels from roughly -5 to +5 volts.

Referring to figure 6, notice that the LEVEL control actually raises or lowers the d-c level of the input to the voltage discriminator. However, this action has the effect of raising or lowering the trigger voltage levels at the input to the difference amplifier.

The purpose of an input trigger channel is to produce a reliable pulse output representing that part of the input signal in which the operator is interested. This is achieved only when the LEVEL control is properly adjusted. Before attempting to adjust the control, it is best to visualize the input waveform, noting the shape, a-c amplitude and d-c level. The effect of various control settings is then relatively easy to calculate. Referring to figure 7, notice that:

1. If the signal is small peak-to-peak, the trigger voltage levels may be set so high or so low that no pulses are produced. In figure 7, for example, if the "positive-going trigger voltage" were set at +1 volts, the attenuated signal with peaks at +2 and +9 volts would not intersect either trigger voltage level.

2. If the input voltage variations ride on a d-c level, they may not come within the trigger voltage range.

3. Modulation or variations in the d-c level of the attenuated signal are least likely to subtract pulses if the trigger voltages are set about halfway between the peaks of the signal.

4. Extraneous voltage variations (noise, hum, modulation, drift, etc.) have the least effect on the time at which a pulse occurs when the channel triggers on a steep slope of the waveform.

5. Noise below 0.4 volts peak-to-peak will not trigger extraneous pulses. Consequently, attenuating a signal carrying a given percentage of noise may eliminate the effect of the noise. For example, 2-volt peak-to-peak noise on a 30-volt peak-to-peak signal will trigger extraneous pulses. If the signal is attenuated by a factor of 10, the resulting 0.2 volt p-p noise is well below the sensitivity of the channel.

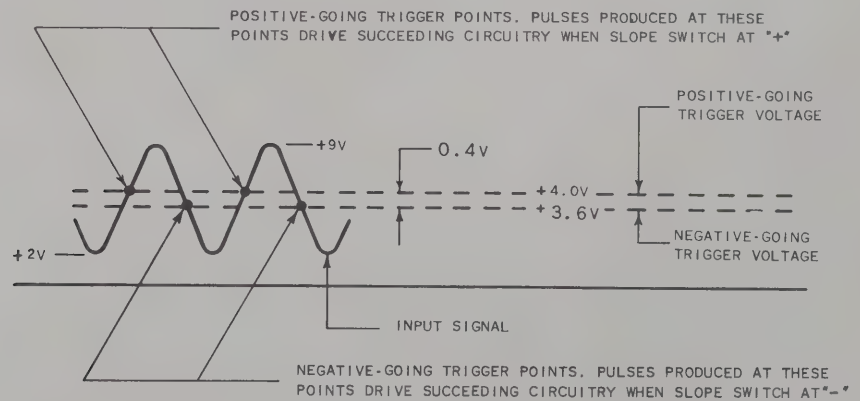

POSITIVE-GOING TRIGGER POINTS. PULSES PRODUCED AT THESE POINTS DRIVE SUCCEEDING CIRCUITRY WHEN SLOPE SWITCH AT "+"
POSITIVE-GOING TRIGGER VOLTAGE
+9V
0.4V
+4.0V
+3.6V
+2V
NEGATIVE-GOING TRIGGER VOLTAGE
INPUT SIGNAL
NEGATIVE-GOING TRIGGER POINTS. PULSES PRODUCED AT THESE POINTS DRIVE SUCCEEDING CIRCUITRY WHEN SLOPE SWITCH AT "-"

FIGURE 7. TRIGGERING ACTION ON INPUT WAVEFORM

Adjustment of LEVEL control should be made keeping the above characteristics in mind. When using any regular periodic input signal, consistent E/UT or PERIOD readings are a good indication that the controls are properly adjusted.

The point on an input waveform where the input channel triggers may be seen on an oscilloscope. Observe the input of the voltage discriminator in the input channel (pin 8, V102). The waveform which appears is the amplified input signaltogether with small "notches" created on each slope as the channel triggers. Rotating the LEVEL control will cause these notches to move up and down the waveform. See "Typical Waveforms" for a sample display.

The trigger voltage may be set at a precise value by applying a d-c voltage of that value at the input jack and rotating the LEVEL control to the point where an output pulse is produced. With no input voltage, the input jack lies at ground and a pulse will be produced at ground level. Some information about the position of the trigger voltage relative to the signal may be extracted from the instrument itself. The trigger voltage may be varied between the positive and negative peaks of an attenuated signal whose peaks lie within the range -5 to +5 volts. As the trigger voltage passes beyond the signal peaks, the pulse output of the channel will cease and these positions of the control may be noted.

ACCURACY

Measurements are subject to three important sources of error.

1. Counts missed or added as the Gate opens and closes.
2. Clock signal inaccuracy.
3. Errors in the time a start or stop pulse is triggered.

<u>One.</u> Pulses which occur simultaneously with the opening or closing of the Gate may or may not be counted. This causes all measurements to vary plus or minus one count. The following equation defines the possible error introduced.

$$(1)\ \text{Max. \% error} = \frac{1}{\text{Count Indication}} \times 100.$$

Notice that measurements set up to yield the highest count indication will be most accurate.

<u>Two.</u> All measurements requiring a time signal (i.e. all measurements except COUNT) are subject to an additional error introduced by variations in the line frequency.

Three. Measurements using an external signal to trigger start and stop pulses (i.e. PERIOD) may be subject to a further error caused by pulses which are triggered too soon or too late. Refer to figure 8 which illustrates what occurs during a simple period measurement. Consider the total signal as an ideal signal intended to trigger the input channel plus a noise signal. The noise voltages added or subtracted from the ideal signal may trigger a pulse before or after the instant at which counting should begin or end. The maximum error in the time of triggering will be proportional to the noise amplitude and inversely proportional to the slope of the ideal signal at the trigger level. Expressed mathematically,

$$(2)\ t\ (\text{secs}) = \frac{V_n\ (\text{volts})}{S\ (\text{volts/sec})}$$

where t = Max. error in trigger time
V_n = peak-to-peak noise
S = slope of ideal signal at trigger level

The total noise (V_n) is equal to that carried by the input signal after attenuation plus that internally generated by the input channel. The internal noise (which takes the form of amplifier drift, trigger level jitter, line frequency pick-up, etc.) is not more than 10 millivolts. Note that as the amplitude of the input signal is increased, S in equation (2) becomes larger and the internal noise causes less error.

The percentage error may be calculated by dividing the error in trigger time by the counting period and multiplying by 100. In the common case of a period measurement of a sine wave triggering at its zero cross-over value:

$$(3)\ \text{Max. \% error} = \frac{V_n\ (\text{volts})}{V_s\ (\text{volts}) \times \pi} \times 100$$

where V_n = peak-to-peak noise
V_s = peak-to-peak signal

The total error due to the three causes mentioned above is equal to the sum of the separate errors.

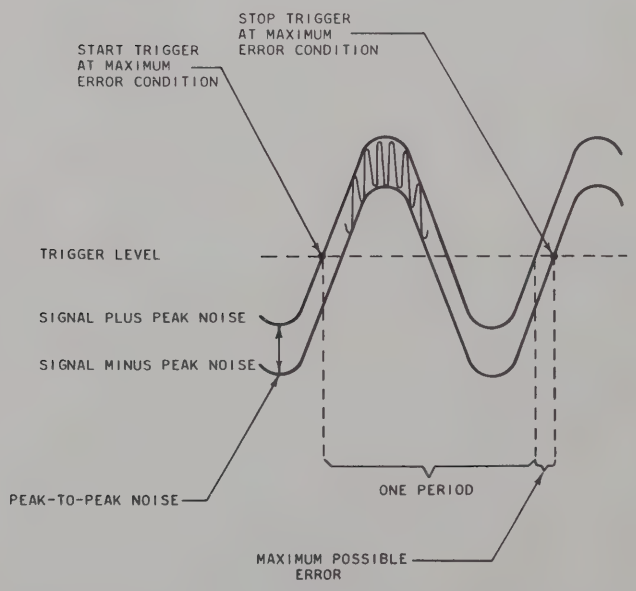


FIGURE 8. EFFECT OF NOISE ON ACCURACY OF PERIOD MEASUREMENT

CIRCUIT DESCRIPTION

OVER ALL DESIGN

(Refer to Block Diagram, Figure 16)

The heart of the instrument is the chain of decimal counting units which register and indicate the number of pulses passing through the electronic gate. The gate itself is equipped with control circuitry which will open and close it in response to pulses of the same size and shape as those which are counted. Thus, each counting operation requires three pulse signals: a "start" pulse to open the gate, pulses to be counted, and a "stop" pulse to close the gate. The remainder of the instrument consists primarily of circuits which generate suitable pulses for these purposes. One of the pulse sources is the input trigger channel ; this generates one pulse for each input signal cycle. The other pulse source is the time base generator; this generates clock pulses of several pulse intervals. The TIME switch selects the clock pulse interval which will be used.

The function performed by the instrument depends entirely upon which pulse source supplies each of the three pulse signals required. The FUNCTION switch selects a pulse source for each purpose; the count section selects the source of pulses to be counted; the start section selects the source of the pulse which starts counting and the stop section selects the source of the pulse which stops counting. For example, with the FUNCTION switch at E/UT (as it is shown in figure 16) the time base generator provides start and stop pulses, while the input channel provides pulses to be counted. The selection of pulse sources for other functions can be found by examining figure 16.

The COUNT function differs slightly from the other operations. With the FUNCTION switch at COUNT, the first pulse from the shaper opens the gate. Notice, however, that there is no source of stop pulses; counting is halted by moving the switch to OFF, thus disconnecting the source of pulses to be counted, while the gate remains open. The gate does not close until the manual RESET button is depressed, when the reset pulse produced affects the control circuitry in the same way as a stop pulse.

INPUT TRIGGER CHANNEL

(See Schematic Diagram, Input Channel, Gate and Control Circuitry)

This channel produces an output pulse each time the input signal passes a selected voltage level. The output is independent of input waveform. The channel consists of a voltage discriminator (a Schmitt trigger circuit) preceded by a difference amplifier. The output of the difference amplifier is proportional to the input voltage on the grid of V101A minus a selected constant voltage on the grid of V101B. The level potentiometer (R105) varies the voltage on the grid of V101B between -5 and +5 volts.

The voltage discriminator (V102) produces an output pulse each time the input voltage on the pentode control grid passes through a fixed voltage level (about +40 volts). Consider the input to this circuit as an a-c triggering signal superimposed on a d-c level.

The a-c signal is an amplified reproduction of the input signal. The d-c level is determined by the voltage on the grid of V101B, a voltage set by the LEVEL potentiometer. As the control is rotated toward "+", the d-c level is lowered and the discriminator triggers at a more positive point on the a-c voltage waveform. When the LEVEL control is turned toward "-", the channel triggers at a more negative point on the a-c waveform.

The discriminator (V102) is a two-stage positive feedback amplifier. Feedback from the output stage occurs through the cathode coupling. The circuit tends to assume one of two stable states. The output stage draws a steady current as long as the input grid remains below a certain triggering voltage. As the input approaches the triggering voltage, the input stage begins to conduct, the loop gain becomes slightly greater than one, and a regenerative action occurs which causes the plate current of the input stage to rise rapidly at the same time that the output stage is cut off. When the input voltage falls to a value slightly below the initial triggering voltage, a reverse regenerative action returns the circuit rapidly to its initial state.

The difference between the level at which a positive going voltage change triggers the circuit and the lower level at which a negative-going voltage change re-triggers it is called the hysteresis of the circuit. At the input to the difference amplifier the hysteresis is about 0.4 volts. The hysteresis determines the input sensitivity. An input signal weaker than 0.4 volts peak-to-peak will not trigger a series of pulses. This means that any noise at the input jack below this level will not trigger extraneous pulses, although it may affect the time at which a pulse occurs.

The primary winding of T101 differentiates the rapid current changes in the output stage to produce a positive pulse at the plate when the circuit is triggered by a positive-going voltage and a negative pulse when triggered by a negative-going voltage. The secondary of T101 produces inverted pulses -- a negative pulse when the circuit is triggered on a positive slope and a positive pulse when triggered on a negative slope.

TIME BASE GENERATOR

(See Schematic Diagram, Time Base Generator and Power Supply)

Purpose. The Time Base Generator provides:

1. Pulses of a known frequency which are counted between start and stop pulses to make time measurements.
2. Start and stop pulses separated by a known time interval over which events are counted to make events-per-unit-time measurements.

The circuitry consists of a pulse shaping circuit and two multivibrator frequency dividers. The shaper stage transforms the sinusoidal 60 cps signal from the power supply into appropriate pulses. The first divider divides the shaper output frequency by six to obtain 10 cps pulses. The second divider divides by ten to obtain a 1 cps pulse signal. Frequencies from the shaper and each of the dividers are selected by the TIME switch and applied to the FUNCTION switch, where they are available for use as start pulses, stop pulses or pulses to be counted.

Shaper. The shaper stage (V402) shapes the 60 cps sine wave for use as an input to the control circuitry and the dividers. The circuit is a voltage discriminator which operates in the same way as

that discussed under "Input Trigger Channel". The trigger voltage level is fixed and the hysteresis is about 8 volts. The primary of T301 differentiates the rapid current changes at the output plate to produce fast positive pulses. The secondary produces negative transients which drive the first divider. Both negative and positive pulse outputs are coupled to the TIME switch. Output at both polarities are required because pulses to be counted must be positive, whereas start and stop pulses must be negative.

Frequency Dividers. The dividing chain consists of two cascaded monostable multivibrators. The first produces one output pulse for every six input pulses. The second produces one output pulse for every ten input pulses. Both dividers operate in the same way; the action will be described with reference to the second, V303. With no input the circuit is stable; V303B is conducting because its grid is connected to +108V DC and V303A is cut off. A negative input transient is coupled through R319 and R316 to each of the two plates. The negative pulse produced on the plate of triode A is coupled by C309 to the grid of triode B. It appears as an amplified positive pulse at the plate of triode B. Since this plate is coupled to the grid of triode A through C307, triode A conducts, driving its plate even further negative. This regenerative action produces a quasi-stable state in which triode B is cut-off and triode A is conducting.

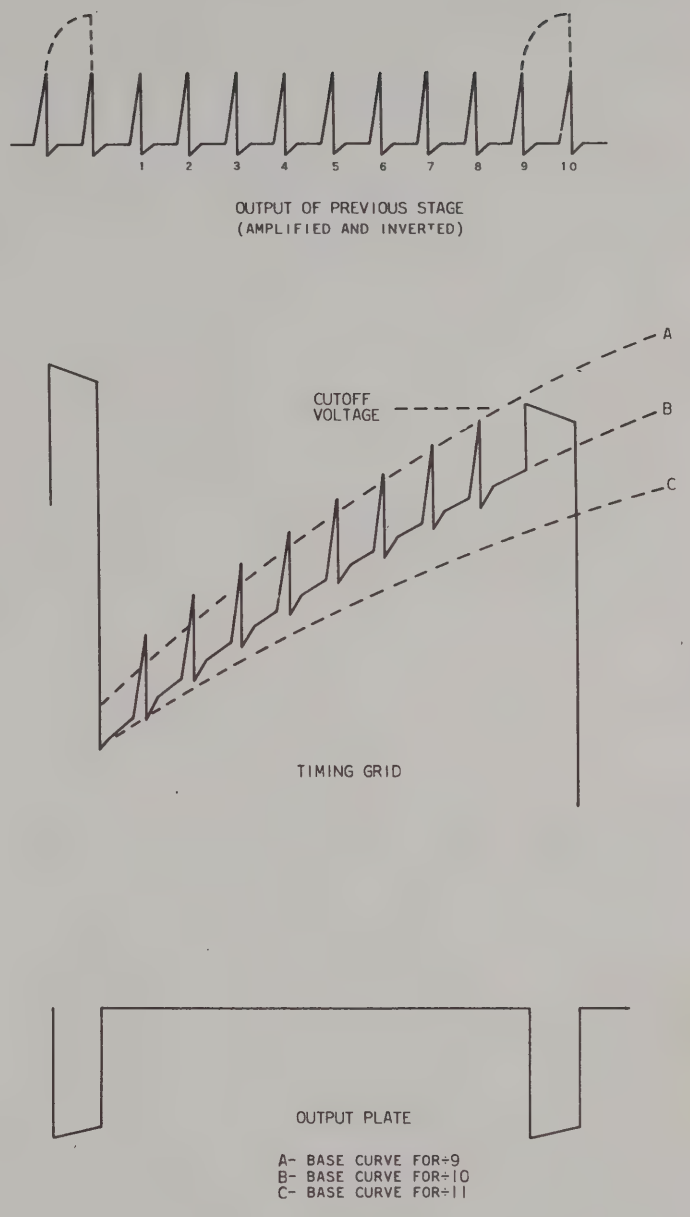


FIGURE 9. SECOND DIVIDER WAVEFORMS

In this state the voltage on the grid of triode B (called the "timing grid") is rising relatively slowly as the voltage at the wiper of potentiometer R327 charges the timing capacitor (C309) through R324. At the same time, negative input pulses at the plate of triode B reach the grid of triode A through C307 and appear as large positive pulses at the plate of triode A. These pulses reach the timing grid through C309 and appear superimposed on the rising voltage curve there. (See Figure 9). When one of the positive pulses brings the timing grid above cut-off, the triode B conducts and a reverse regenerative action returns the circuit to its original stable state. The slope of the rising grid voltage curve determines which of the successive positive pulses will rise above cut-off. The slope changes when the charging voltage at the wiper of potentiometer R327 is raised or lowered. R327 is adjusted so that the ninth pulse rises above cut-off. The

tenth pulse returns the circuit to the quasi-stable state. (See "Routine Maintenance" for directions on adjusting R327 and corresponding potentiometer in the other divider, R326.

In the interval between the ninth and tenth pulses, triode B is conducting and its plate is negative. The transient produced is the useful output of the divider. It is conduced to the TIME switch where it is available as a clock signal. This switch is labelled with the pulse interval of the divider output selected.

POWER SUPPLY

(See Schematic Diagram, Time Base Generator and Power Supply)

The power supply is a conventional transformer-rectifier-filter arrangement employing selenium rectifiers. It generates two positive d-c supplies: an unregulated +190-volt supply and a +108-volt supply regulated by a VR tube. It also creates two negative d-c supplies: an unregulated -110-volt supply and a -60-volt supply regulated by a 1N210 diode. The supply voltages mentioned above are nominal only. See "Troubleshooting" for information on the actual d-c level required and permissable ripple.

GATE & CONTROL CIRCUITRY

(See Schematic Diagram, Input Channels, Gate & Control Circuitry)

The Gate and control circuitry receive three pulse inputs from the FUNCTION switch (S103): pulses to be counted, start pulses, and stop pulses. Pulses to be counted go from Deck C to the signal grid of the Gate tube (V106). The plate of this tube is coupled to the first of the cascaded DCU's. During the period its suppressor grid is at ground, the tube amplifies the grid signal and drives the DCU's. In this state the Gate is "open". When the suppressor grid is below -10 volts, the tube is cut off and the Gate may be considered "closed".

The "open-close" voltages on the Gate tube suppressor grid are generated by the control Flip-Flop (V104). The voltages appear at the plate of triode V104B. V104 is a conventional "flip-flop" circuit having two stable states: left triode conducting, right triode cut off; and right triode conducting, left triode cut off. Input pulses or transients applied at various points on the circuit will trigger it back and forth between the two states. When triode B is conducting, its plate is 65 volts negative of ground. A negative start transient from the start flip-flop, applied at the plate of triode A and coupled through C113 to the grid of triode B, triggers V104 to its other stable state. In this state, triode B is cut off and its plate moves positive far enough to permit the Gate tube to conduct. When a negative stop pulse from Deck B of the FUNCTION switch reaches the grid of V104A through the diode CR103, V104 is triggered back to the state which holds the Gate closed.

The Start Flip-Flop (V103) is also a circuit with two stable states. It produces a negative start transient at the plate of triode B each time that triode begins to conduct. The grid of triode A is coupled to Deck A of the FUNCTION switch through the diode CR101 and C104. When triode A is conducting, a negative start pulse at the grid triggers a change to the other stable state producing the output transient. Further negative pulses at the grid of triode A have no effect since that half is already cut off.

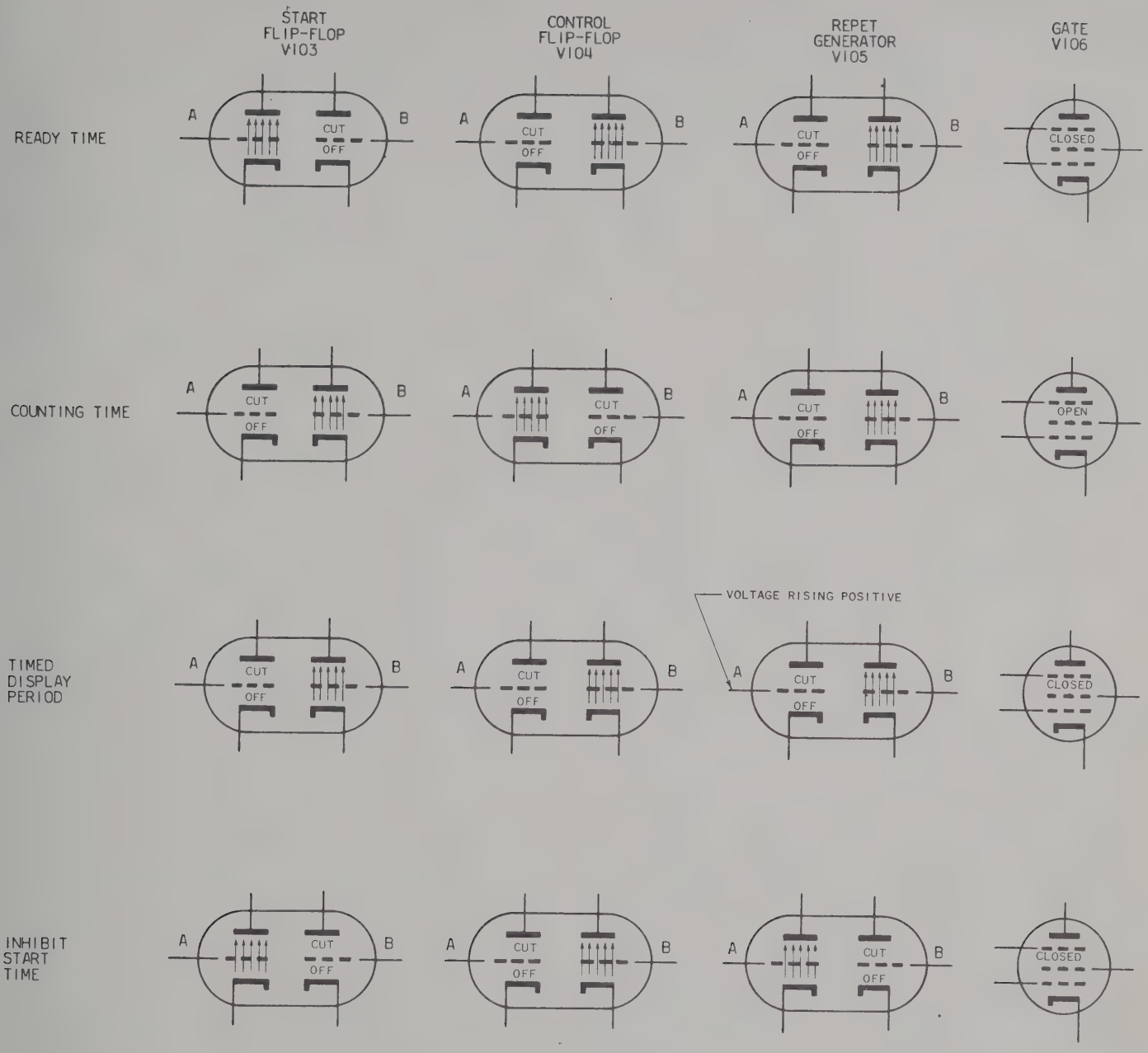


FIGURE 10. STATE OF TUBES IN THE CONTROL CIRCUITRY DURING THE FOUR-PART OPERATING CYCLE.

When the instrument is ready to begin a counting period, triode B of the Control Flip-Flop and triode A of the Start Flip-Flop are conducting. In this state, the Gate is closed. Negative stop pulses received at the grid of V104A have no effect since this triode is cut off. The following sequence occurs. (Refer to Figures 12 & 13.)

Time (1) A start pulse passes through the injection diode CR101 and triggers the Start Flip-Flop which in turn triggers the Control Flip-Flop to a state which opens the Gate. The DCU's then count and indicate the number of pulses reaching the Gate.

Time (2) A stop pulse triggers the Control Flip-Flop to a state which closes the Gate.

At this point, if the instrument is set to operate automatically, the reset circuitry begins to function. The reset control voltage appears at the junction of R121 and R137. Its value is determined by the combined effect of the voltage on the plate of V103A and that on the plate of V104A. At the close of a counting period (and only then) both these plates are at approximately -10V DC. The resulting positive charge at the junction leaks on to C114 through the DISPLAY time potentiometer, R138. C114 is coupled to the grid of V105A. When this grid rises above cut-off at time (3), the Reset Generator (V105) produces a pulse which resets all the DCU's to zero.

The Reset Generator is a one-shot multivibrator. In its stable state, V105B is conducting because its grid is connected to B+, and V105A is cut off. When the grid of V105A becomes sufficiently positive, that triode begins to conduct and V105B is cut off momentarily by a negative pulse produced at the plate of triode A and coupled to grid of triode B by C117. The reset pulse appears at the plate of V105A. This pulse is conducted to all the DCU's and also the Start and Control Flip-Flops. The pulse returns both flip-flops to the stable state existing before the start pulse, although under automatic operation, the Control Flip-Flop is already in this state.

The Reset Generator also produces a positive pulse at the plate of V105B. This pulse, which occurs simultaneously with the reset pulse, is coupled to the cathode of the start injection diode (CR101) through R113, C105 and R114. The positive charge created at the cathode prevents negative start pulses from reaching the Start Flip-Flop until all reset transients have decayed. At time (4), about 25 milliseconds after the reset pulse, the control circuitry is ready to accept another start pulse.

When the DISPLAY time control is turned fully clockwise, the positive voltage connection to this potentiometer is broken by S102 and the automatic reset action will not occur. The DCU's hold the accumulated count until the manual RESET button is depressed. Depressing this button actuates S105, connecting the +190-volt supply to C114 and connecting the Reset Generator input grid to -110V DC. When the button is released, the positive charge on C114 flows on to the Reset Generator input grid and initiates the same reset action that occurs under automatic operation.

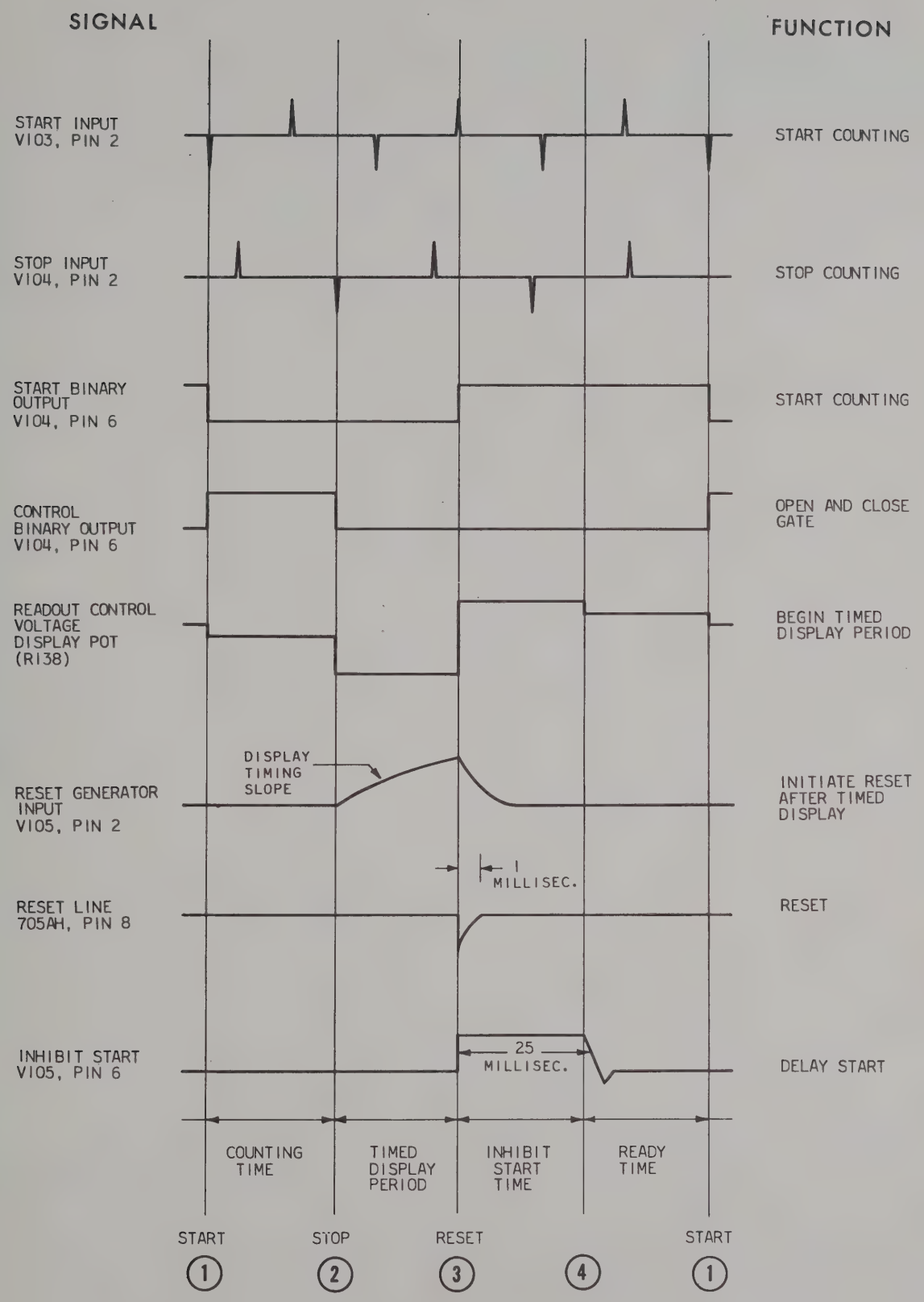


FIGURE 11. TIMING DIAGRAM OF CONTROL CIRCUITRY ACTION

DECIMAL COUNTING UNITS

The DCU's are connected in cascade, output of one to input of next. All are identical. The output of the gate tube (V106) drives the "units" DCU (AY102) which counts pulses from one to nine returning to zero on the tenth pulse and simultaneously sending a drive pulse to the "tens" DCU. Consequently, the tens DCU registers one count for every ten pulses from the gate and sends one drive pulse to the "100's" DCU for every one hundred gated pulses. In a similar way the 1000's DCU registers one count for every 1000 gated pulses. These units are described in greater detail in an appendix to this manual.

ROUTINE MAINTENANCE

Adjusting the Time Base Dividers. Two potentiometer controls, located on the rear panel, should be adjusted whenever the instrument fails to give correct indications under TEST operation. The line voltage during adjustment should be either exactly 117v (in which case the adjustment will be correct for line variations of ±10%) or the actual line voltage that the instrument is to be operated on. Each control is adjusted while measuring the voltage at the test jack beside it. Place the FUNCTION switch at TEST, then start with the 10^{-1} SEC control and proceed to the 1 SEC. Rotate each control back and forth to the extremes of the range in which the proper count indication appears, noting the test jack voltage at each extreme. Then, position the control so that the test jack voltage is midway between the extreme values.

For example, with the TIME switch at 10^{-1}, rotate the 10^{-1} control clockwise until the count indication changes from 6 to 7. As the reading changes from 6 to 7, the voltage at test jack E-3 might +78v. Then, rotate the control counter-clockwise until the count indication changes from 6 to 5. The test jack voltage at that time might be +68v. In this case, position the control so that test jack voltage is 73v, a value midway between +68 and +78v. Adjust the other controls similarly.

In the absence of a d-c voltmeter, it is possible to position the controls by estimating the center of the rotational arc within which the correct indication appears. However, this adjustment is not likely to be so precise as that obtained with the use of a voltmeter, and re-adjustment may be necessary much sooner.

	Place TIME Switch at	Adjust	Measure voltage at	Proper Count Indication
Step 1	10^{-1}	10^{-1} SEC	E-1	6
Step 2	1	1 SEC	E-0	60

TABLE 1

TROUBLESHOOTING

Equipment Required

1. An oscilloscope, sensitivity 2v/cm, bandwidth d-c to 5Mcs, high impedance input.
2. A signal generator, frequency range 20 cps to 100Kcs, output amplitude 3v rms, calibration accurate to ±5%.
3. A vacuum tube voltmeter, range 1.5 to 300 volts.

Disassembly. To expose the circuitry for repair, remove the two screws on each side of the top of the cabinet and slide the hood covering the top and sides upward.

General Troubleshooting Procedure.

First. Make sure the instrument is being operated properly. Check the operating procedure for the function used with particular attention to use of proper input channel, SLOPE switch setting and LEVEL control position. Under E/UT operation, make sure the counting period is not too short to measure a

low input frequency. Under PERIOD operation, be sure the unit of time measurement is not too great to measure a short period. See that the TIME BASE switch on the rear panel is at INT unless a signal is coupled to the jack below it. Finally, check the input signal for excessive noise.

Second. Check the power supply voltages to see that they lie within the limits listed below.

Supply	Limits of Average Level	Acceptable Ripple
Unreg. Pos.	+187v to +209v	14v p-p
Reg. Pos.	+104v to +112v	2v p-p
Unreg. Neg.	+106v to +120v	11v p-p
Reg. Neg.	+56v to +65v	0.2v p-p

Third. Follow the trouble localization procedure. Components most likely to fail are tubes and crystal diodes; check these first when the trouble has been traced to a certain stage.

Overall Trouble Localization Procedure. After you are sure that the d-c supply voltages are adequate, the next step is to trace the cause of faulty operation to one of the major functional components: an input channel, the time base generator, the DCU's or the gate and control circuitry. Referring to the block diagram in figure 16, notice that not all of these parts are used during certain operations. Therefore, you can eliminate some possibilities simply by rotating the FUNCTION switch and noting which operations fail. For example, if the instrument operates correctly at COUNT but fails during the E/UT operation, the trouble is probably in the time base generator, which is not used during COUNT operation.

Signal tracing with an oscilloscope is the best means of further localizing trouble.

The following are primary test points.

Output of input channel:
test point 4

Output of time base generator:
test points 21, 22, 24 & 26

Output of gate:
test point 14

Output of DCU's:
test points 16, 17 & 18 (pin 4 of each DCU plug)

Localizing Trouble in the Gate Control Circuitry. Signal tracing within each major component is fairly straightforward except in the case of the gate control circuitry. In this case, it may be desirable to study the circuit in each of its three stable states: "ready time", "counting time" and "display time". (See figures 9 and 11). This may be done as follows:

1. Place the FUNCTION switch at PERIOD but apply no input.
2. Turn the DISPLAY control fully clockwise.
3. Place the slope switches at "+".
4. Press the RESET button. After a 15-millisecond "inhibit start" period, the circuitry will switch to the "ready time" state.
5. Rotate the LEVEL control back and forth once. This generates a pulse which should trigger the control circuitry to the "counting time" state.
6. Rotate the LEVEL control back and forth once again. The pulse generated should trigger the circuitry to the "display time" state.

Localizing Trouble in the Time Base Generator. The signal path in this part runs from the shaper straight through to the last divider. When viewing the signal at a test point on a divider, be sure to position the TIME switch to select the output of that divider. This insures that loading effects will be the same as those encountered in actual operation.

Localizing Trouble in a Decimal Counting Unit. See the appended instruction manual on the decimal counting unit for directions.

RECOMMENDED SPARE PARTS

Beckman/Berkeley Stock No.	Description	Number of Spares for Specified Operating Period 500 hrs.	1000 hrs.	5000 hrs.
2-5747	Capacitor, Metalized Paper, .25 μf, 200 V DC Hopkins Engineering P2520	0	1	2
2-2230	Capacitor, .01 μf, Ceramic Disc, Erie 811	0	1	3
2-5793	Capacitor, .001 μμf, Ceramic Disc, 1KV Centralab DD102	0	1	3
2-5630	Capacitor, 125 μf, 350 V DC, Electrolytic Sangamo PL35125	0	0	1
2-5245	Capacitor, 80 μf, 250 V DC, Electrolytic Sangamo PL2580	0	0	1
5-6777	Tube, type 6211	1	10	15
5-6072	Tube, type 6AN8	1	3	5
5-6929	Tube, type 5915	0	1	2
5-0531	Tube, type OB2	0	1	2
5-2362	Tube, type 5963	2	10	20
6-6779	Transformer, pulse 1:1, 7 mh Pulse Engineering ES6-5	0	0	1
7-0504A	Fuse, 2 Amp Slo Blo, Littlefuse 313002	0	1	3
8-4184	Diode, 1N67A	0	1	3
8-5580	Diode, 1N95	0	0	1
8-5579	Diode, 9GA2	0	0	1
8-S4369	Diode, 1N210 National Semi-Conductor	0	0	1
8-4425	Diode, Silicon, 500 ma, 130 V rms, Sarkes Tarzian M500	0	1	3
8-7045	Diode, Texas Industries, type 600C	0	0	2

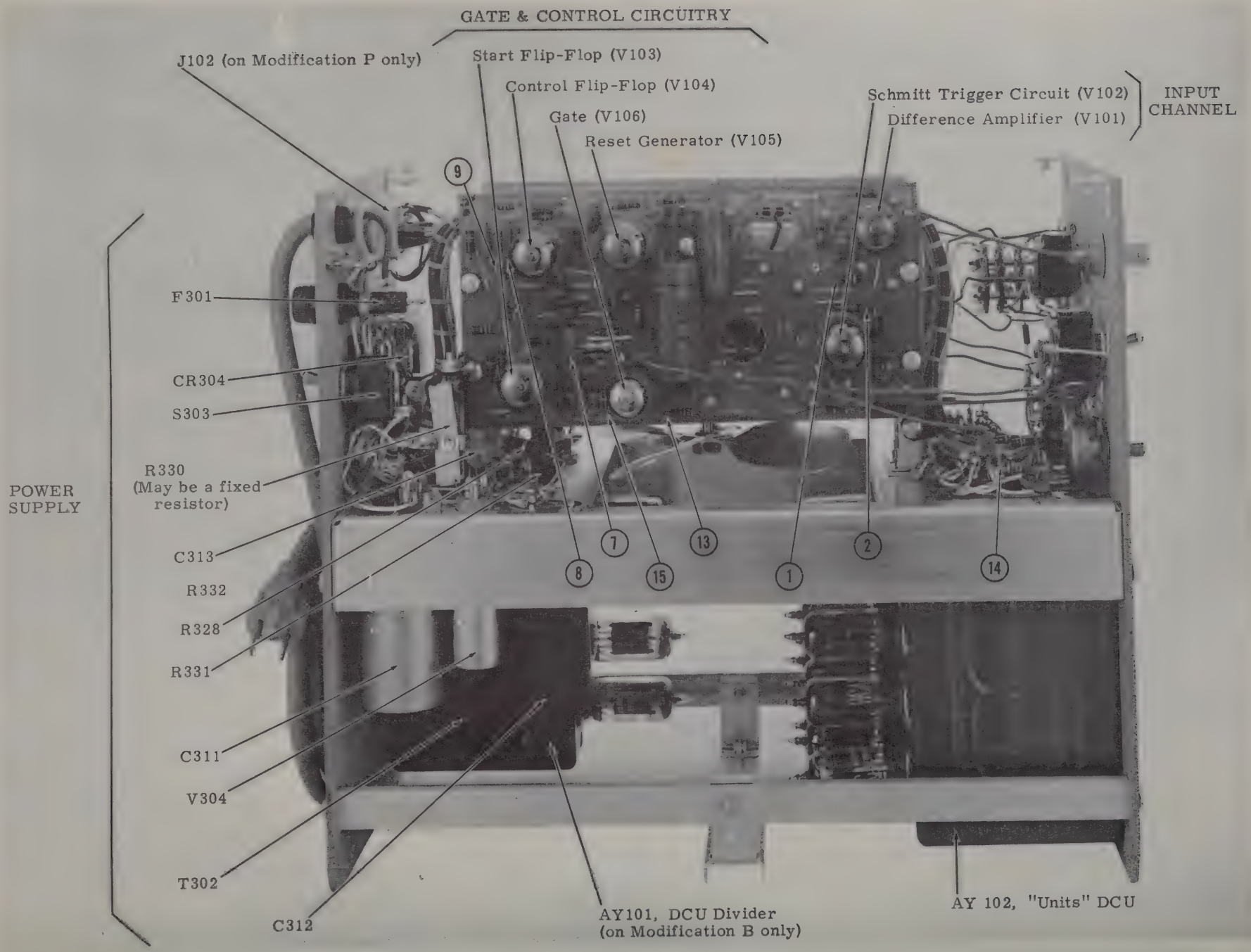
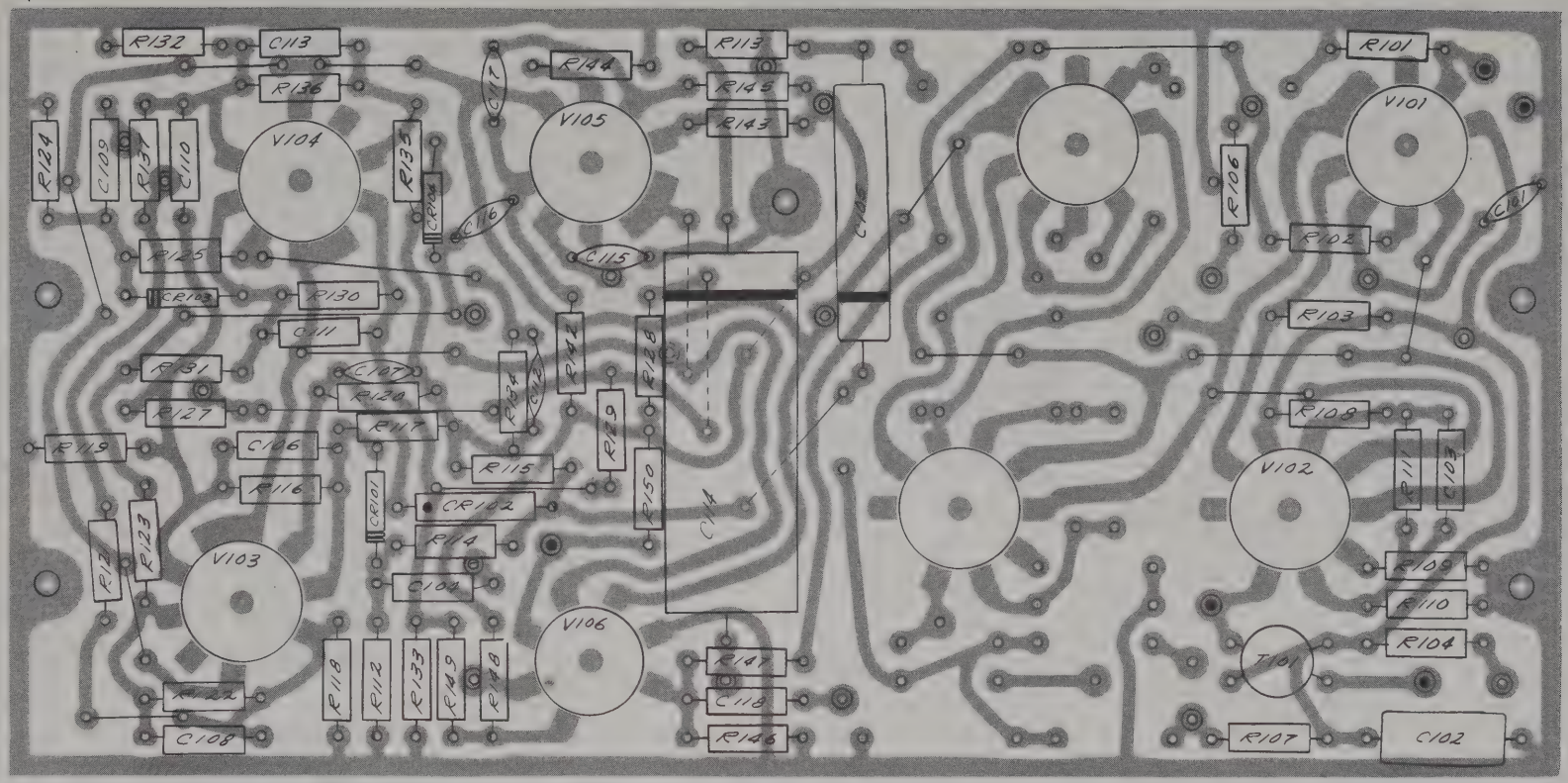


FIGURE 12. INTERIOR VIEW OF RIGHT SIDE. CIRCLED NUMBERS INDICATE TEST POINTS. THIS IS A MODEL 5210BP FROM PRODUCTION LOT 1. LOTS MAY DIFFER IN MINOR DETAILS. SEE WIRING DIAGRAM FIGURE 13. FOR IDENTIFICATION OF PARTS ON PRINTED CIRCUIT BOARD.



◉ LUGS NEAR SIDE

◎ LUGS FAR SIDE

FIGURE 13. WIRING DIAGRAM OF TERMINAL BOARD APPEARING IN FIGURE 12.

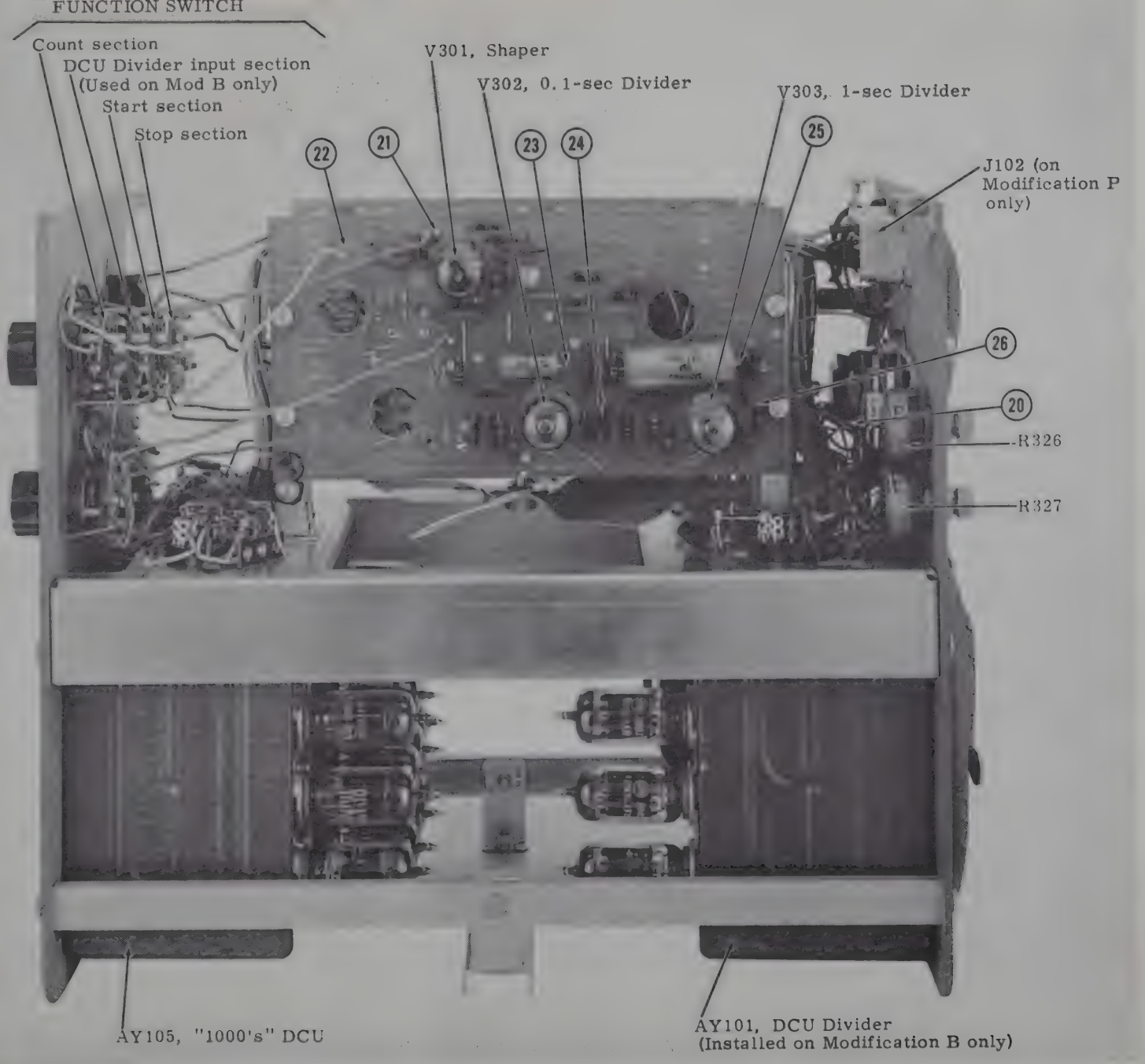
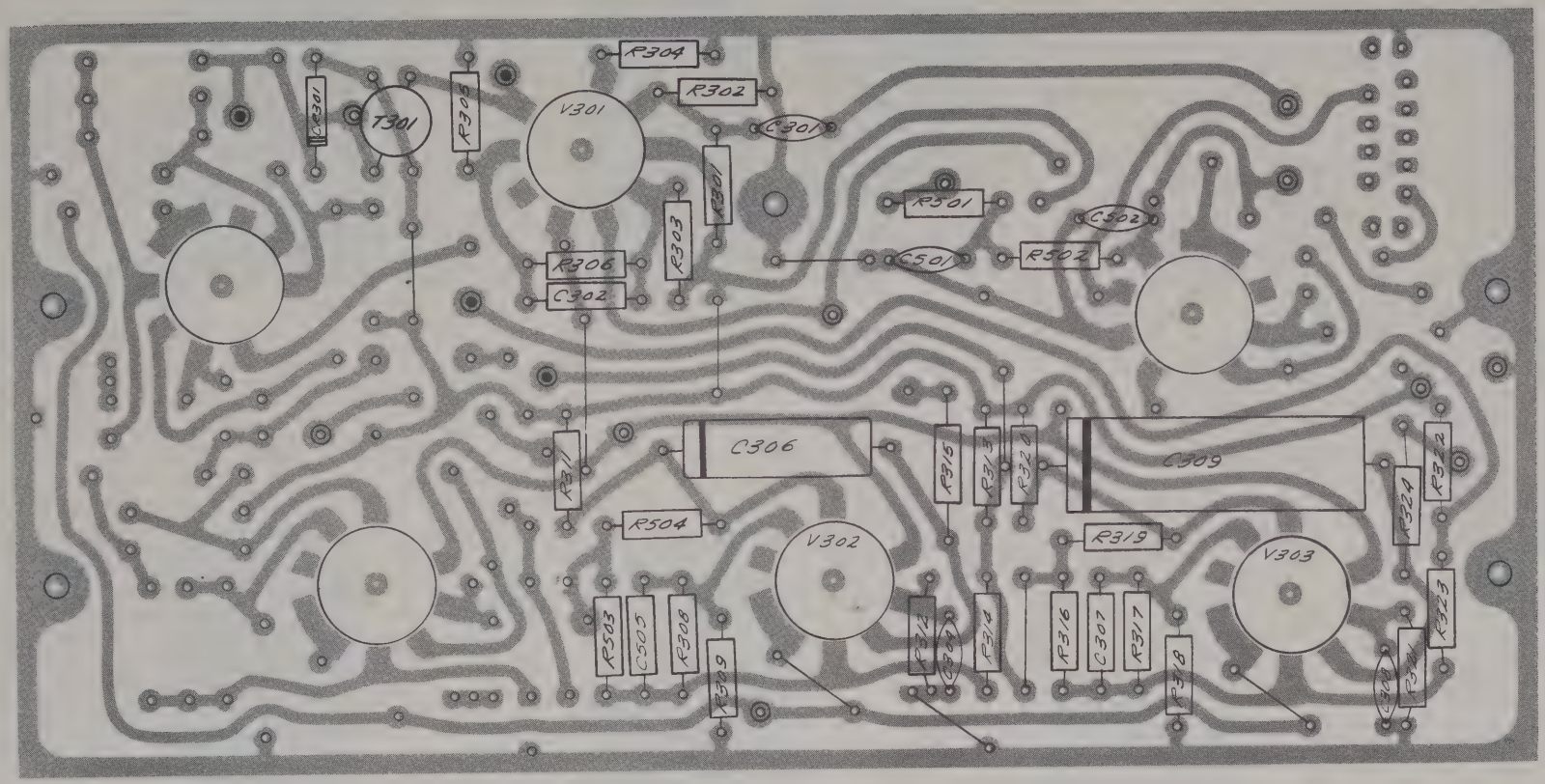


FIGURE 14. INTERIOR VIEW OF LEFT SIDE. CIRCLED NUMBERS INDICATE TEST POINTS. THIS IS A MODEL 5210BP FROM PRODUCTION LOT 1. LATER LOTS MAY DIFFER IN MINOR DETAILS. SEE WIRING DIAGRAM FIGURE 15 FOR IDENTIFICATION OF PARTS ON PRINTED CIRCUIT BOARD.



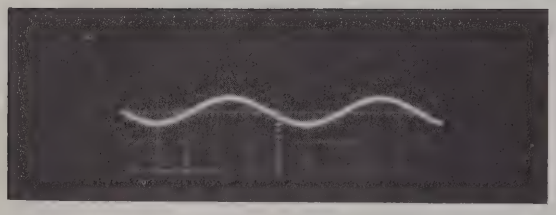
◉ LUGS NEAR SIDE

◎ LUGS FAR SIDE

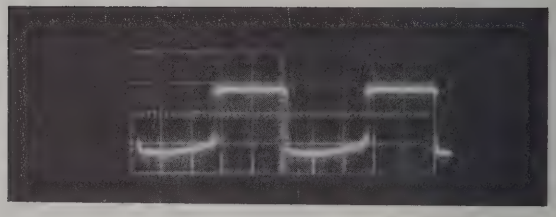
FIGURE 15. WIRING DIAGRAM OF TERMINAL BOARD APPEARING IN FIGURE 14.

TYPICAL WAVEFORMS

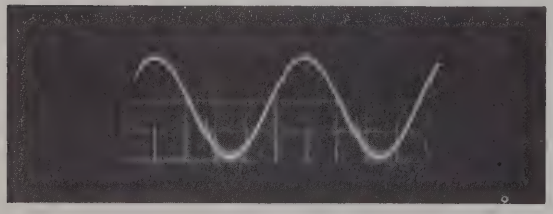
The waveforms which appear on the following pages were obtained with a Tektronix type 541 oscilloscope equipped with type 53/54C preamplifiers. Scope input resistance was 10 megohms. Input was a-c coupled unless otherwise noted. The circled numbers under the pictures designate test points so labeled on the schematic diagrams and, in many cases. on the photographs of the interior. In all waveforms positive polarity is up, negative is down.



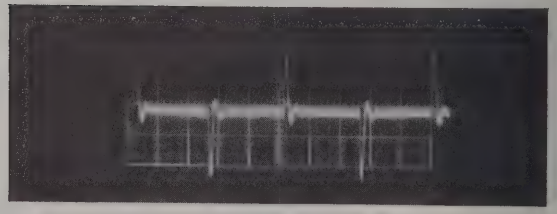
(0) 10Kcs signal at input jack (0.5v/cm, 20μsec/cm) This is approximately the minimum amplitude which will successfully trigger the channel.



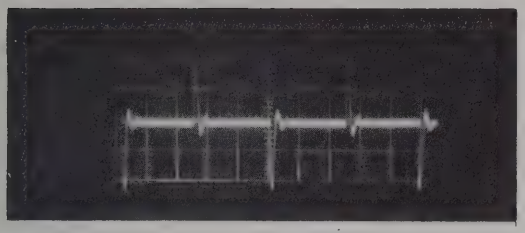
(2) Pentode plate of Schmitt trigger, V102 (10v/cm, 20μsec/cm) The two voltage levels correspond to the two stable states of the trigger circuit.



(1) Input to Schmitt trigger, V102 or V202 (2.5v/cm, 20μsec/cm). Small notches show points on waveform where circuit triggers. Hysteresis at this point is approximately 5v. Positive-going trigger voltage here is about +48v; negative-going trigger level is about +43v.



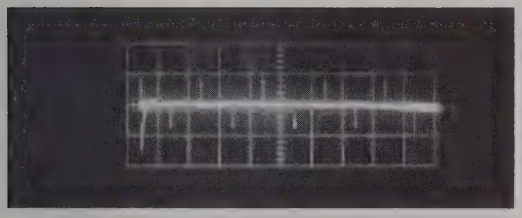
(3) Non-inverted output of Schmitt trigger, V102 (5v/cm, 20μsec/cm). This signal is formed by differentiating a current waveform corresponding to the waveshape at test point 2.



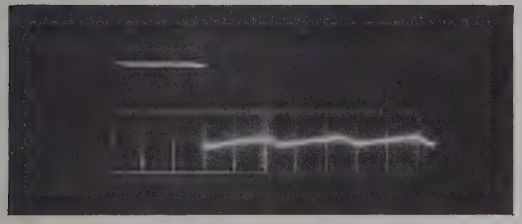
(4) Inverted output of Schmitt trigger, V102 (5v/cm, 20μsec/cm)

(5) "Start" pulses appear here but are best observed at input to start flip-flop (test point 7) where pulses have been affected by coupling capacitor C104.

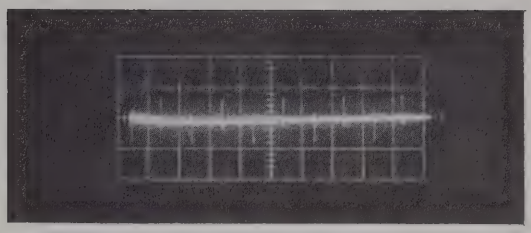
(6) "Stop" pulses appear here but are best observed at input to control flip-flop (test point 9) where pulses have been affected coupling capacitor C109.



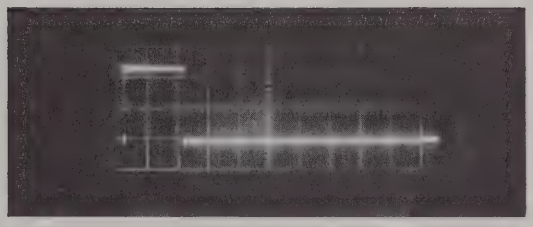
(7) Input to start flip-flop, V103 (10v/cm, 500μsec/cm) 1Kcs input to channel produces these pulses with FUNCTION switch at PERIOD.



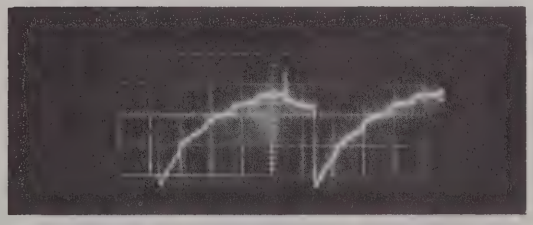
(8) Output at plate of start flip-flop, V103. (20v/cm, approx 6ms/cm) Top horizontal grid line is ground level. FUNCTION switch at TEST, TIME switch at 10^{-1}, DISPLAY control fully counterclockwise. Trace begins at reset, which triggers flip-flop to -10v output level; after "inhibit start" period, a start pulse triggers it to the -60v output level.



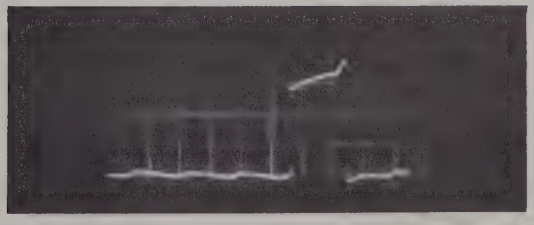
(9) Input to control flip-flop, V104 (10v/cm, 500μsec/cm) 1Kcs input to channel produces these pulses with FUNCTION switch at PERIOD.



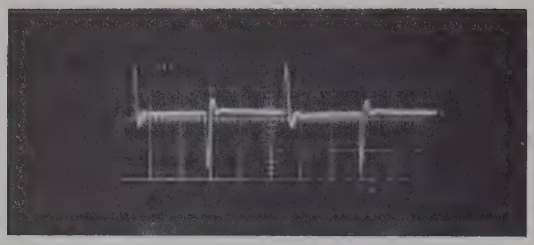
(10) Output of control flip-flop, V104 (20v/cm, 500μsec/cm) Trace begins at time of "start" pulse. Gate is open during upper voltage plateau (approx-10v), closed during lower voltage plateau. (approx. -60v)



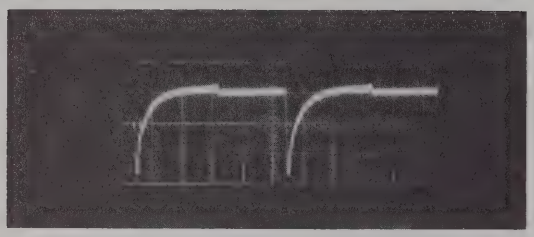
(11) Display timing slope at input to reset generator, V105. (20v/cm, 20ms/cm) Calibrated center line is at ground. Reset occurs at time of sharp positive spike.



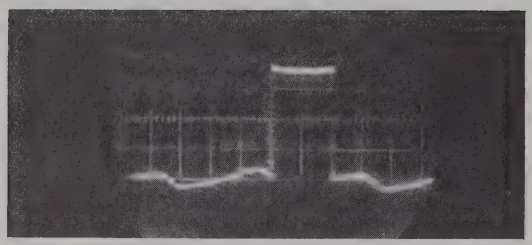
(12) Inhibit start signal at output of reset generator, V105 (20v/cm, 10ms/cm) Positive transient occurs at reset. Start flip-flop is prevented from triggering for duration of positive pulse.



(13) Gate (V106) input from channel (5v/cm, 20μsec/cm) FUNCTION switch at COUNT. Uppermost horizontal grid line is ground level. Only positive pulses generate output pulses.

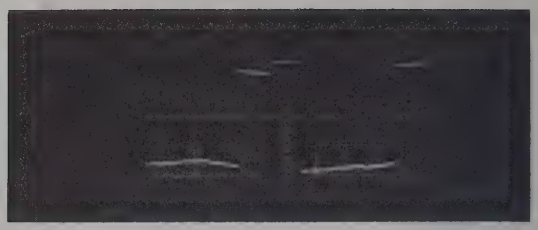


(14) Output of gate (V106) with FUNCTION switch at COUNT. (50v/cm, 20μsec/cm)



(15) Gating signal at suppressor grid of gate tube, V106 (10v/cm, 5ms/cm) Horizontal grid line second from top is approx. ground level.

Trace begins at reset. Gate is open during time signal is slightly above ground.

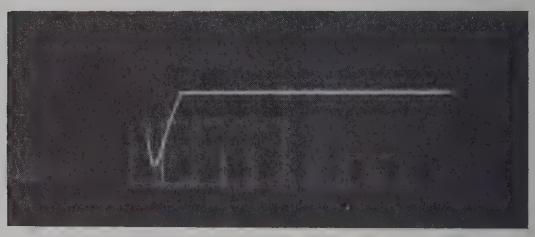


(16) Output of "units" DCU, AY102, with 1Kcs input. (20v/cm, 2ms/cm)

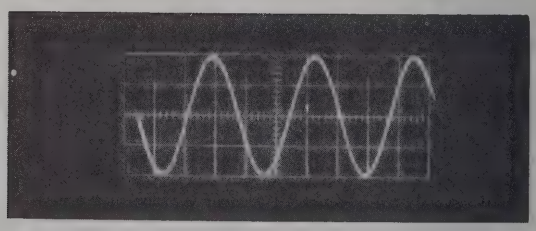
70-volt negative transient drives next DCU. This picture shows almost two complete cycles.

(17) Output of "tens" DCU, AY102. Same as waveform at test point 16 except cycling period is ten times as long.

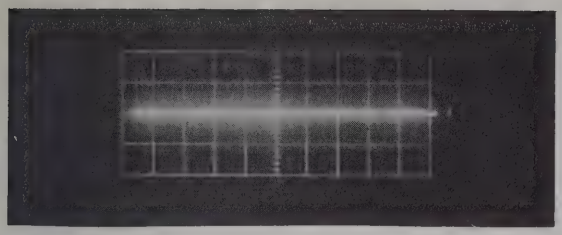
(18) Output of "100's" DCU, AY104. Same as waveform at test point 16 except cycling period is 100 times as long.



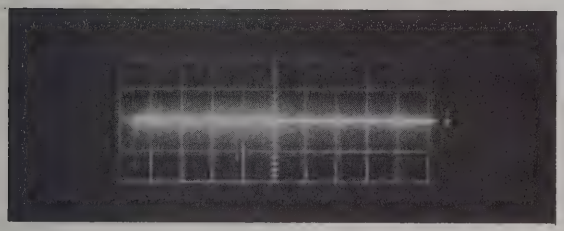
(19) Reset pulse from V105 (20v/cm, 200μsec/cm)



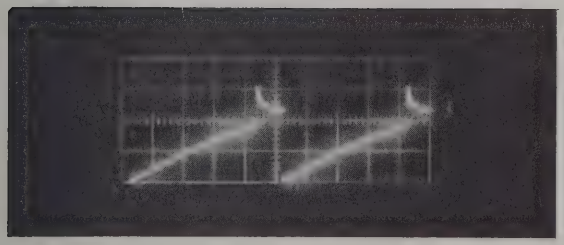
(20) 60 cps input to shaper, V301 (10v/cm, 5ms/cm)



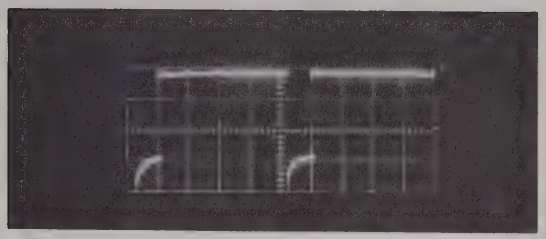
(21) Positive pulse output of shaper, V301 (10v/cm, 5ms/cm). The fast, brief 15-volt pulses are barely visible in this picture.



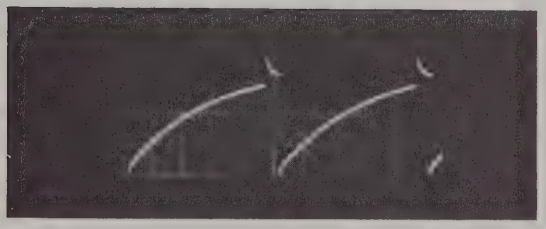
(22) Negative pulse output of shaper, V301 (10v/cm, 5ms/cm) The signal consists of very fast 15-volt pulses, barely visible in this picture.



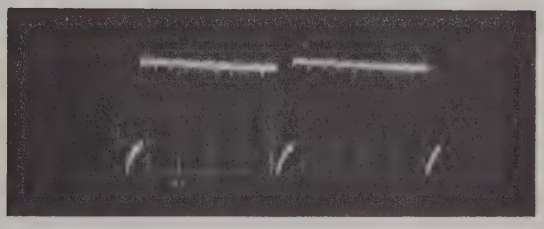
(23) Timing grid of 0.1-second divider, V302 (20v/cm, 20ms/cm) This stage divides by six. The four narrow pulses superimposed on the rising voltage curve are not visible in the picture, but may be seen on an oscilloscope. When attempting to obtain this display on a scope, be careful not to load the circuit excessively. Excessive loading will be evident by a change in the front-panel count indication, if the FUNCTION switch is at TEST.



(24) Output of 0.1-second divider, V302 (5v/cm, 20ms/cm). Pulse interval here is 0.1 secs



(25) Timing grid of 1-second divider, V303 (15v/cm, 200ms/cm). See note under waveform 23 for scope load precautions. This stage divides by 10.



(26) Output of 1-second divider, V303. (5v/cm, 200ms/cm) Pulse interval is one second.

TYPICAL VOLTAGE AND RESISTANCE READINGS

Ordinarily readings may vary 10% from the value listed without causing trouble. Tube sockets are difficult to reach with a probe in this instrument, but tube pins may be exposed by pulling the tube about 1/16" out of the socket, being careful not to break the connection to socket terminals. Special conditions of measurement are indicated by letter superscripts, ("a", "b", "c", etc.), and the notes to which they refer. Otherwise conditions are as follows:

1. Line voltage 117 volts.
2. LEVEL controls set to trigger at ground level.
3. FUNCTION switch at OFF.
4. DISPLAY control fully clockwise.
5. Instrument in "ready time" condition, that is, after reset and before start pulse.

Tube	Pin No.	D-C Volts with respect to ground.	Resistance to ground in Ohms.
V101	1	+105	9.8K
	2	0	1M
	3&8	+4.2	92K
	6	+4.0	120K
	7	+3.0	10K[a]
V102	1	+105	98K
	2	+43/+36[b]	27K
	3&9	+46/+72[b]	12K
	6	+94/+80[b]	18K
	7	+105	98K
	8	+13/+71[b]	120K
V103	1	-9/-65[c]	23K
	2	-99/-87[c]	47K
	3&8	-86	18K
	6	-65/-9[c]	26K
	7	-87/-99[c]	62K
V104	1	-9/-65[c]	23K
	2	-99/-87[c]	26K
	3&8	-86	18K
	6	-65/-9[c]	25K
	7	-87/-99[c]	62K
V105	1	+190	125K
	2	-32 to +17[d]	88K
	3&8	+29	27K
	6	+90	20K
	7	+28	12.M
V106	1	11.1	180K
	2	0	0
	5	+190	88K
	6	+180	98K
	7	-42/+4.7[e]	230K
V301	1	+108	9.4K
	2	+43	27K
	3&9	+58	12K
	6	+87	17K
	7	+108	9.4K
	8	+39	110K
V302	1	+61	28K
	2	+21	120K
	3&8	+23	8.2K
	6	+97	28K
	7	-1.5	3.9M
V303	1	+57	28K
	2	+22	120K.
	3&8	+23	8.2K
	6	+103	28K
	7	+20 to -20[f]	3.9M

a. Reading should vary from 0 to 50K as LEVEL control is rotated.

b. Two readings obtained, one with LEVEL control at each of two extreme positions.

c. Two readings obtained, one with flip-flop in each of two stable states. The 9-volt reading at pins 1 and 6 may vary as much as 2 volts.

d. Reading obtained during 5-second automatic display. Reading varies from -32v immediately after end of counting period to +17v just before reset.

e. Two readings obtained, , one with gate open, one with gate closed.

f. This divider cycles so slowly that the rising voltage curve on the timing grid is observable with a voltmeter.

MODIFICATIONS

INTRODUCTORY NOTE

Modified instruments are identified by one or more letters after the model number. For example, Model 5210B is a standard Model 5210 EPUT Meter modified as described below under "Modification B". An instrument may be modified in more ways than one: for instance, Model 5210BP is a Model 5210 changed in accordance with both "Modification B" and "Modification P". The entire instructiom manual except this section on modifications describes a standard instrument.

CONTENTS

Modification B, "X10" Extension of Counting Period
Modification P, Binary-Coded Readout Facilities

MODIFICATION B

This consists of adding a decimal counting unit which will divide the frequency of "start" and "stop" pulses by ten. This DCU is switched into and out of the circuit by the FUNCTION switch which has extra positions labelled "X10".

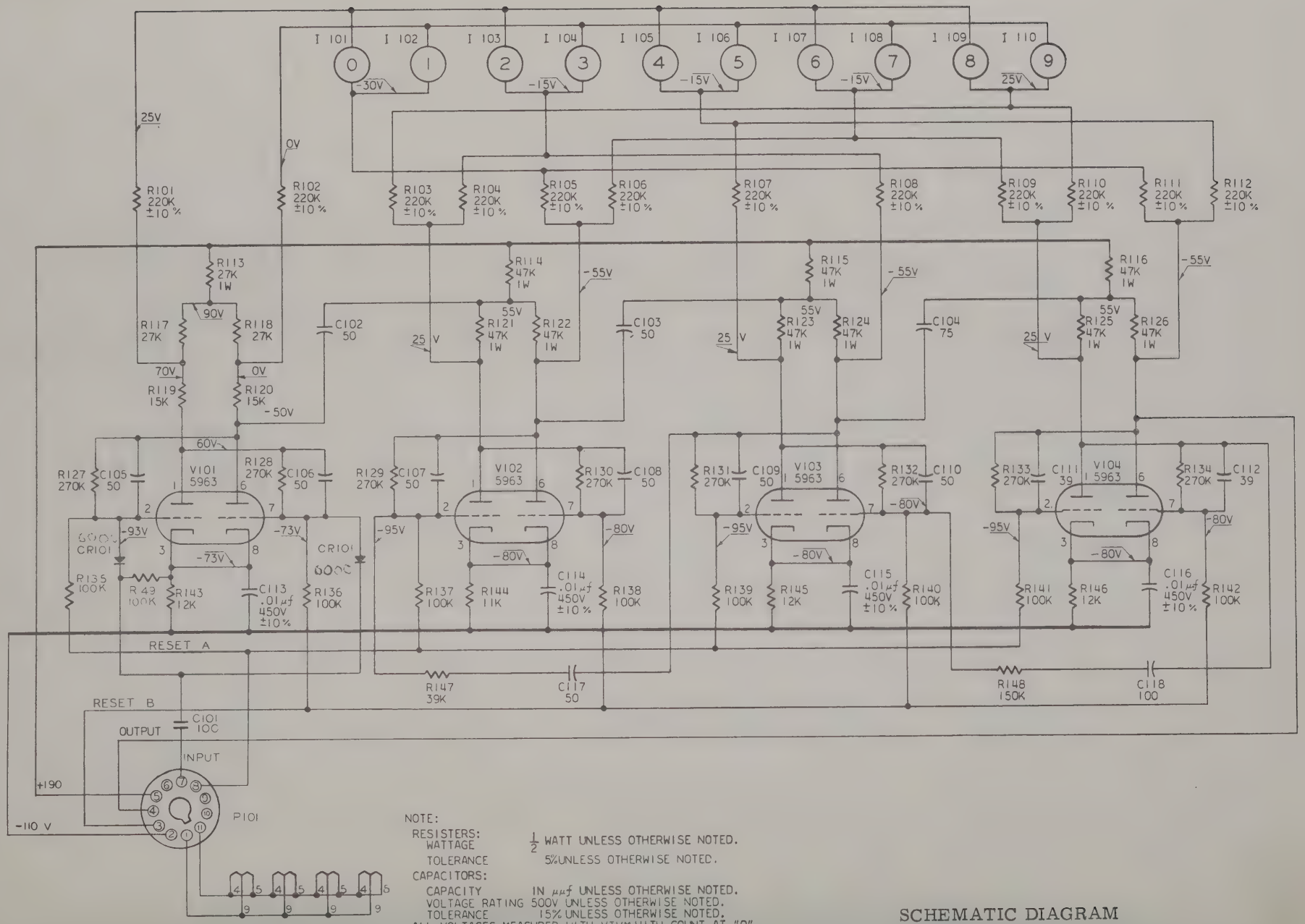
When the FUNCTION is at one of the "X10" positions, the counting period is ten times as long as it would ordinarily be. For example, with the switch at E/UT X10, the time interval during which events are counted is 10 times that indicated by the TIME switch. With the switch at PER X10, the instrument measures the length of ten periods, or, more generally, the time between the first voltage excursion through the trigger level at the B input jack and the tenth following excursion of the same polarity. With the switch at A/B X10, the instrument counts the number of cycles at the A input which occur during ten cycles at the B input.

The divider DCU is a Model 705AL. This DCU is nearly identical to the Model 705AH DCU's which register and indicate the count. The principal difference is that the first binary stage of the 705AL is driven by pulses applied directly to the grids, instead of by pulses applied to the plates and coupled to the grids by the cross-over network. Another difference is that the 705AL does not generate a binary-coded readout.

A schematic diagram of the 705AL appears on the following page. The remaining circuit changes necessary to accommodate the modification appear within dashed lines on "Schematic Diagram, Input Channel, Gate and Control Circuitry".

NOTE

Modification B makes it possible to extend the counting period of the instrument to 10 seconds or even longer. Because of the extended counting time, the maximum automatic display period may be much less than five seconds. A longer display can be obtained by rotating the DISPLAY control clockwise until a switch clicks audibly, but in this case the instrument must be reset manually.



NOTE:

RESISTERS:
WATTAGE — $\frac{1}{2}$ WATT UNLESS OTHERWISE NOTED.
TOLERANCE — 5% UNLESS OTHERWISE NOTED.

CAPACITORS:
CAPACITY — IN μμf UNLESS OTHERWISE NOTED.
VOLTAGE RATING 500V UNLESS OTHERWISE NOTED.
TOLERANCE — 15% UNLESS OTHERWISE NOTED.

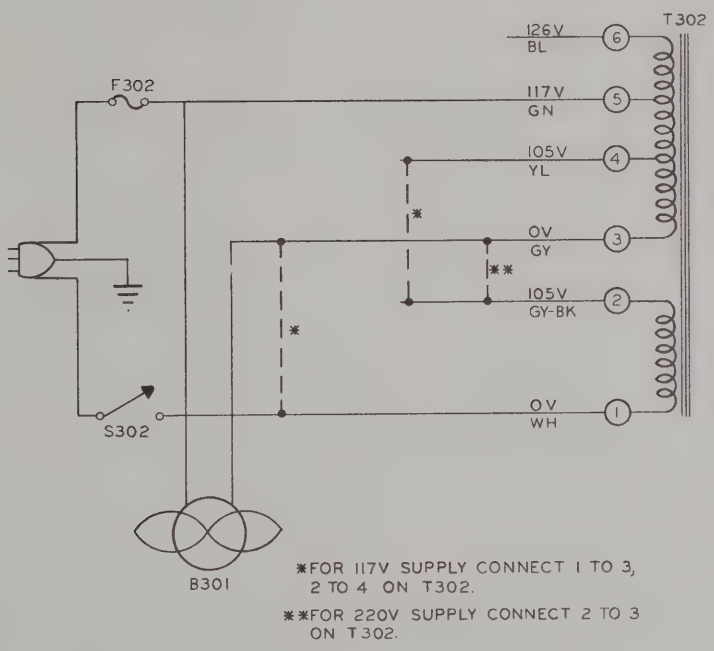
ALL VOLTAGES MEASURED WITH VTVM WITH COUNT AT "0".

SCHEMATIC DIAGRAM
MODEL 705AL
DECIMAL COUNTING UNIT
DWG. NO. 705C601

5210, 5220, 5230 Mod B.

MODIFICATION H

This consists of replacing the standard power transformer with a transformer which can be wired for either 117-volt or 220-volt operation. As shipped the instrument is wired for 220 volts. To re-wire it for 117 volts, follow the directions on the schematic insert below.



SCHEMATIC INSERT, POWER SUPPLY MODIFICATION H

MODIFICATION P

Each Model 705AH DCU generates a modified binary code representing the digit it is displaying. The code consists of a voltage (high or low) on each of four pins of the DCU plug. Modification P consists of connecting the four pins from each DCU socket to a DIGITAL RECORDER jack mounted at the rear of the instrument. Count information is then available at this jack for either the Model 1452 Digital Recorder or the Model 5914 In-Line Readout. Both are equipped with a plug which mates with the DIGITAL RECORDER socket.

The four-line code appears in the table below. "0" represents a voltage 15 or more volts negative of ground; "1" represents a voltage at ground or positive of ground.

DECIMAL DIGIT REGISTERED	FOUR-LINE BINARY CODE			
	1st Binary Stage	2nd Binary Stage	3rd Binary Stage	4th Binary Stage
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	1	1	0
5	1	1	1	0
6	0	0	1	1
7	1	0	1	1
8	0	1	1	1
9	1	1	1	1
No Digit	0	0	1	0

	PIN NO. ON DIGITAL RECORDER SOCKET			
	1st Binary Stage	2nd Binary Stage	3rd Binary Stage	4th Binary Stage
"1000's" digit	Pin 4	Pin 3	Pin 2	Pin 1
"100's" digit	8	7	6	5
"Tens" digit	12	11	10	9
"Units" digit	16	15	14	13

Pin 39 of the DIGITAL RECORDER socket carries a signal from the counter which tells the auxiliary equipment when to collect count information. This pin is negative of ground during the display period and positive of ground from reset until the end of the next counting period.

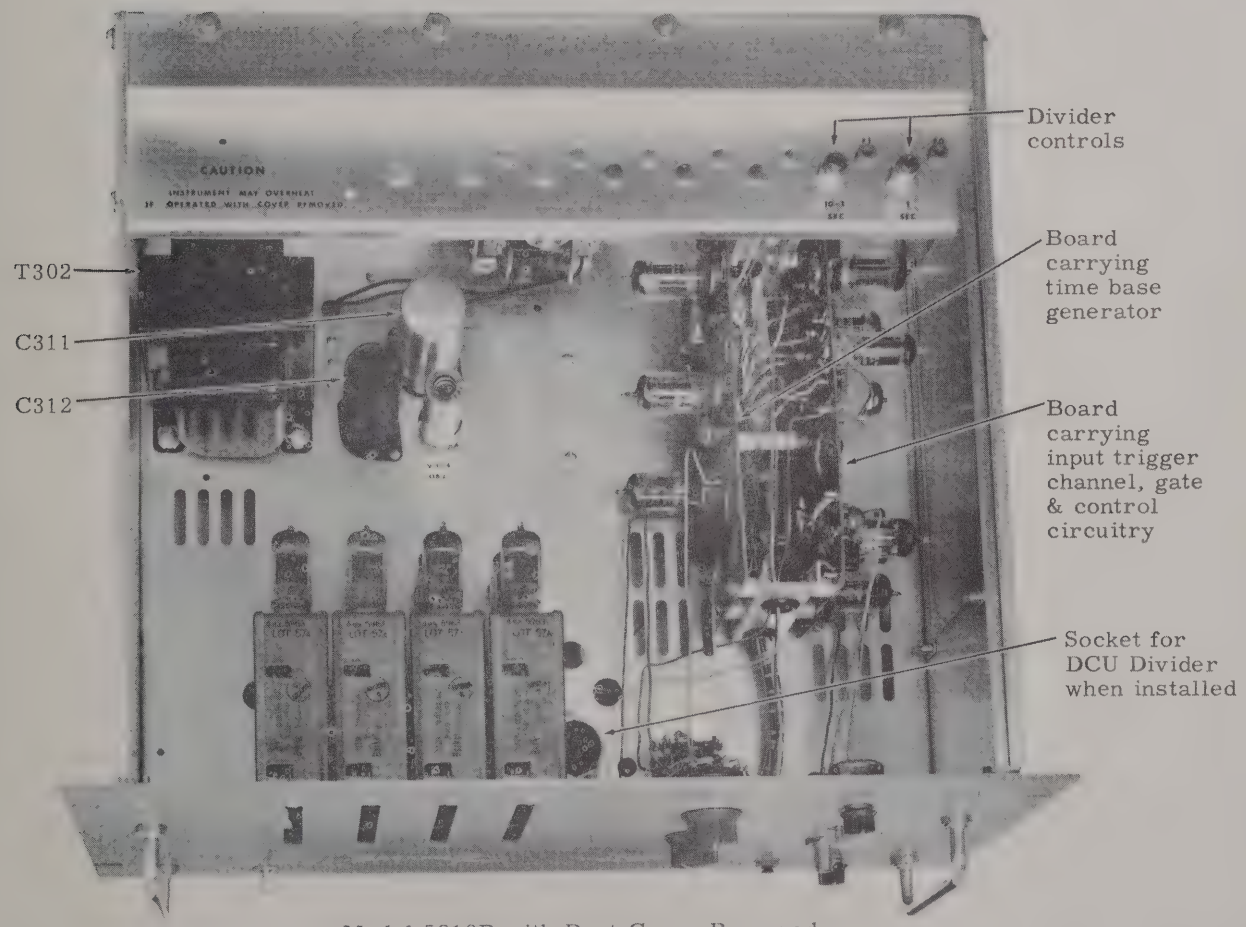
Pin 40 carries a signal from the readout equipment to the counter. The readout device grounds this pin, thus preventing the counter from resetting to zero, until count information has been collected.

All connections between the counting circuitry and the DIGITAL RECORDER jacket are shown on "Schematic Diagram, Input Channel, Gate and Control Circuitry".

MODIFICATION R

This modification is electrically identical to the standard instrument; the only difference is that all components have been transferred to a chassis that can be mounted in a standard 19-inch relay. Dimensions are as follows:

Panel width:	19 inches
Panel height:	8-3/4 inches
Depth behind panel:	16 inches



Model 5210R with Dust Cover Removed.

Component Parts of Models 5220R and 5230R are similarly located.

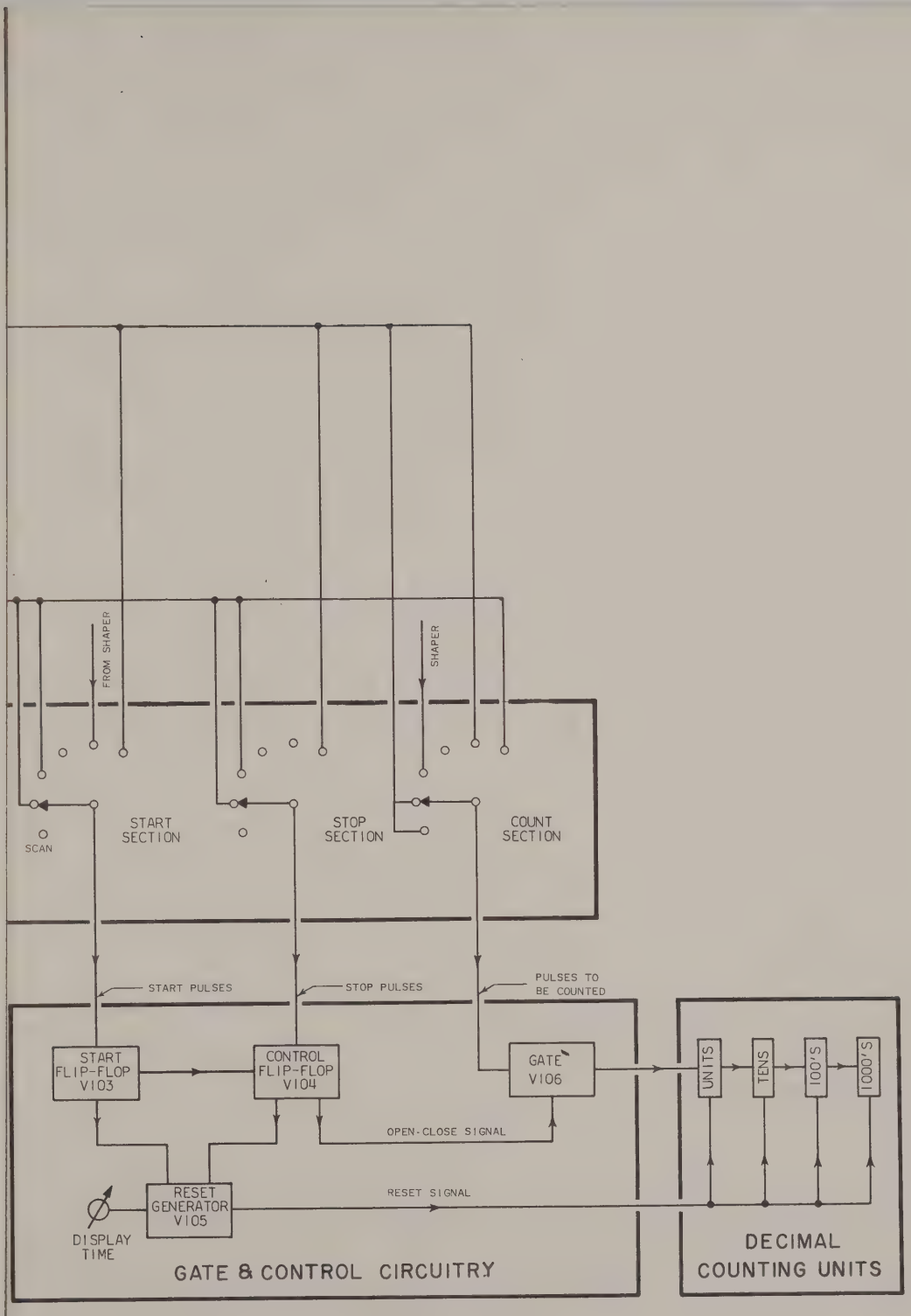


FIGURE 16. BLOCK DIAGRAM, MODEL 5210

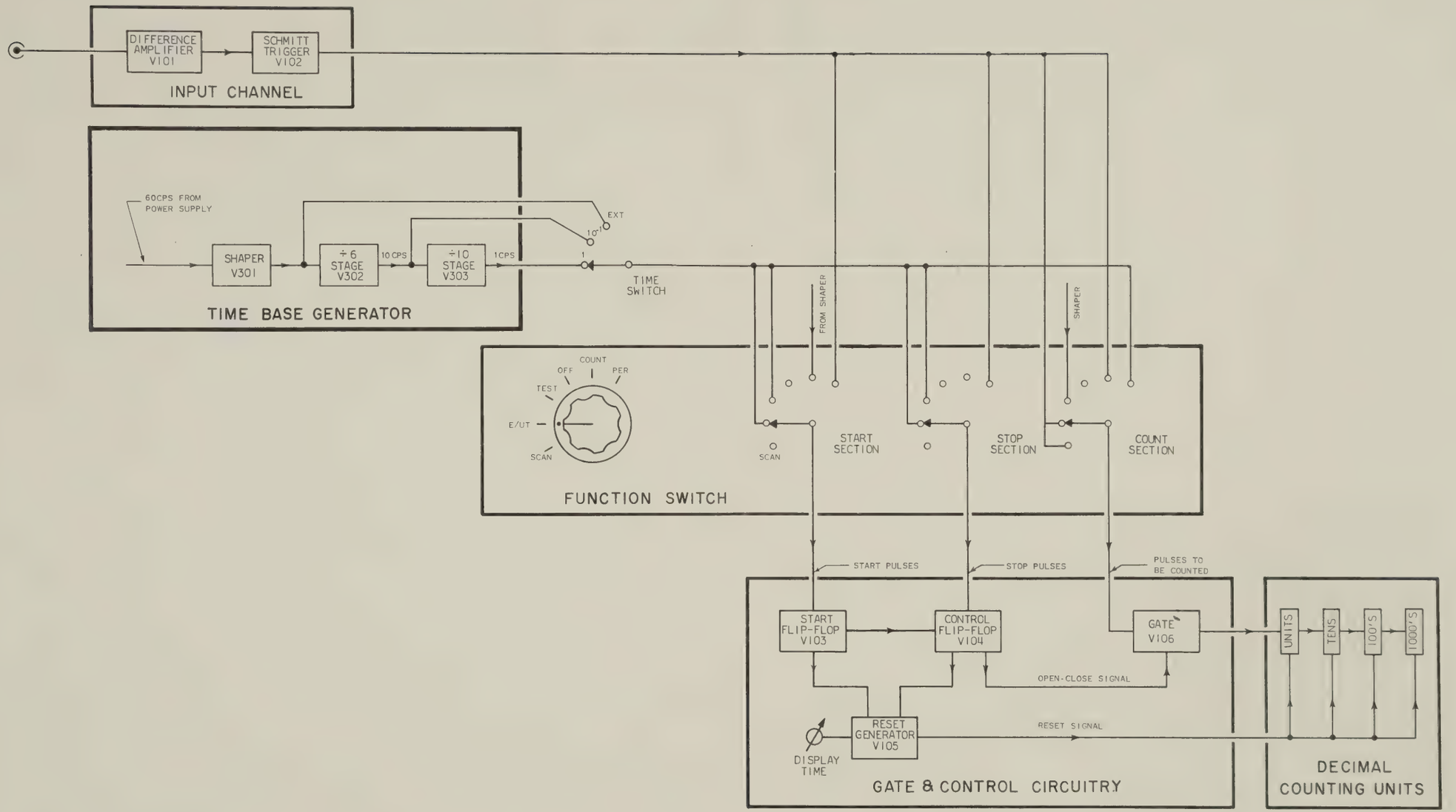


FIGURE 16. BLOCK DIAGRAM, MODEL 5210

PARTS LIST, INPUT CHANNEL , GATE & CONTROL CIRCUITRY

(Refer to Dwg. No. 5210D1)

ABBREVIATIONS

AB	Allen Bradley Company, Milwaukee, Wisconsin
B/BD	Beckman/Berkeley Division
Cap.	Capacitor
IPC	Industrial Products Co., Danbury, Connecticut
IRC	International Resistor Co., Philadelphia, Pennsylvania

NOTE: Any resistor which does not appear in the list below is a fixed composition resistor of the value, wattage and tolerance noted on the schematic diagram. All other electrical components are listed

Detail No.	Stock No.	Description	Manufacturer & No.
AY102, AY103, AY104, AY105		DCU, Model 705AH	B/BD
C101	2-2230	Cap., .01 μf, Ceramic Disc	Erie 811-.01
C102	2-5747	Cap., .25 μf, 200V dc Metalized Paper	Hopkins Eng. p252D
C103	2-2135	Cap., 15 μμf, 500V dc Silvered Mica	Sangamo RR 1415
C104	2-2137	Cap., 500 μμf, 500V dc Silvered Mica	Sangamo RR 1350
C105	2-0763	Cap., .1 μf, 400V dc Plastic Moulded Paper	Sangamo 300401
C106	2-2141	Cap., 50 μμfd, 500V dc Silvered Mica	Sangamo RR 1450
C107		Same as C101	
C108		Same as C106	
C109		Same as C104	
C110	2-3620	Cap., 120 μμfd, 500V dc Silvered Mica	Sangamo RR1312
C111		Same as C106	
C112		Same as C101	
C113		Same as C106	
C114	2-3835	Cap., .5 μfd, 400V dc Plastic Moulded Paper	Sangamo 330504
C115		Same as C101	
C116	2-6492	Cap., .02 μfd, Disc, 400 V	
C117	2-6492	Cap., .02 μf, disc Ceramic	Erie 811-.02
C118	2-1943A	Cap., 150 μμf, 500V dc Silvered Mica	Sangamo RR1315
C119	2-3157	Cap., 39 μμfd, 500V dc Silvered Mica	Sangamo RR 1439
C120 thru C135	2-5793	Cap., .001 μμf Disc Ceramic 1KV	Centralab DD102
C136	2-2608	Cap., 300 μμf, 500V dc Silvered Mica	Sangamo RR1330

Detail No.	Stock No.	Description	Manufacturer & No.
CR101	8-4184	Rectifier, 1N67A	Transitron
CR102	8-5579	Rectifier, 9GA2	IRC
CR103		Same as CR101	
CR104	8-5580	Rectifier, 1N95	IRC
J101	17-3179	Connector, Low Voltage	IPC MS595
R105	1-6774	Potentiometer, 100K, CT 2 W, 10% Carbon	AB JU 1041
R138	1-2956	Potentiometer, 10 M, 2 W, 20% Carbon W/Switch	Centralab BA98
S101	12-1909	Switch, DPDT Bat Toggle	CH8373K7
S102		Part of R137	
S103	12-6778	Switch, 4 Sec, 11 Pos As per Spec. Dwg.	Oak
S104	12-6812	Switch, 1 Sec, 5 Pos. As per Spec. Dwg.	Oak
S105	12-2600	Switch, Push Button DPDT	Switchcraft FF1006
T101	6-6779	Transformer, Pulse	Pulse Eng. ES6-5
V101	5-6777	Tube, 6211	
V102	5-6072	Tube, 6AN8	
V103		Same as V101	
XAY101	4-1720	Socket, 11 Pin Octal Black Bake	Amphenol 77M1P11
XAY102 thru XAY105		Same as XAY101	
XV101	4-4435	Socket, 9 Pin Min for Printed Circuit	Elco 654-PH-J3
XV102		Same as XV101	
XV103 thru XV105		Same as XV101	
XV106	4-4444	Socket, 7 Pin Min for Printed	Elco 654-PH-J4

ADDITIONS

CR105	8-7183	Silicon Diode, HD 6064
C137	2-2230	Cap., .01 Disc 400V

E & CONTROL CIRCUITRY

10D1)

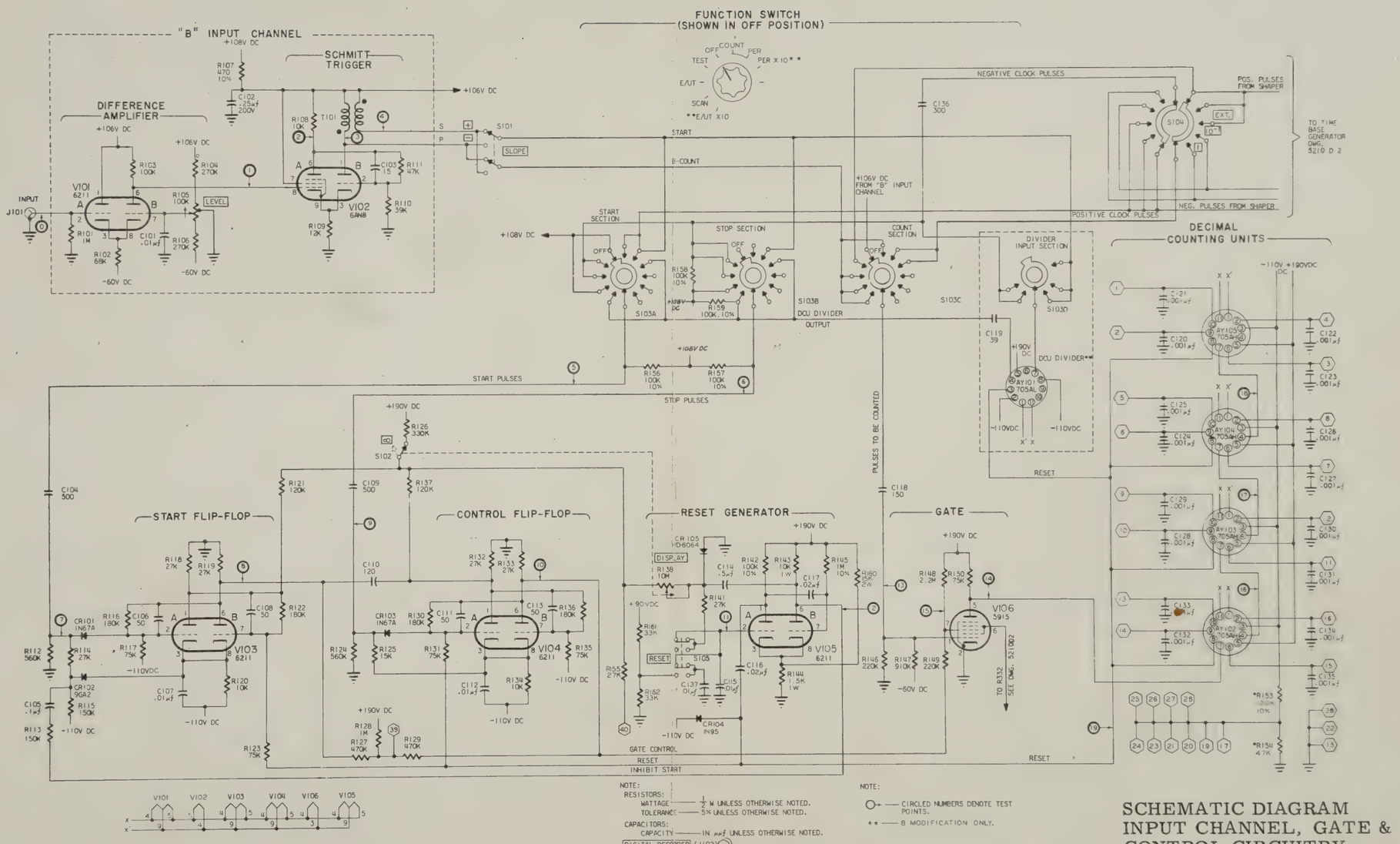
NS

Milwaukee, Wisconsin
ion

., Danbury, Connecticut
., Philadelphia, Pennsylvania

appear in the list below
or of the value, wattage
hematic diagram. All
are listed

ail o.	Stock No.	Description	Manufacturer & No.
01	8-4184	Rectifier, 1N67A	Transitron
02	8-5579	Rectifier, 9GA2	IRC
03		Same as CR101	
04	8-5580	Rectifier, 1N95	IRC
	17-3179	Connector, Low Voltage	IPC MS595
5	1-6774	Potentiometer, 100K, CT 2 W, 10% Carbon	AB JU 1041
8	1-2956	Potentiometer, 10 M, 2 W, 20% Carbon W/Switch	Centralab BA98
1	12-1909	Switch, DPDT Bat Toggle	CH8373K7
2		Part of R137	
3	12-6778	Switch, 4 Sec, 11 Pos As per Spec. Dwg.	Oak
4	12-6812	Switch, 1 Sec, 5 Pos. As per Spec. Dwg.	Oak
5	12-2600	Switch, Push Button DPDT	Switchcraft FF1006
0	6-6779	Transformer, Pulse	Pulse Eng. ES6-5
01	5-6777	Tube, 6211	
02	5-6072	Tube, 6AN8	
03		Same as V101	
Y101	4-1720	Socket, 11 Pin Octal Black Bake	Amphenol 77M1P11
Y102 thru Y105		Same as XAY101	
101	4-4435	Socket, 9 Pin Min for Printed Circuit	Elco 654-PH-J3
102		Same as XV101	
103 thru 105		Same as XV101	
106	4-4444	Socket, 7 Pin Min for Printed	Elco 654-PH-J4



SCHEMATIC DIAGRAM
INPUT CHANNEL, GATE &
CONTROL CIRCUITRY
MODEL 5210
DWG. NO. 5210D1

Sept. 1958

PARTS LIST, TIME BASE GENERATOR AND POWER SUPPLY

(Refer to Dwg. No. 5210D2)

ABBREVIATIONS

AB	Allen Bradley Company , Milwaukee, Wisconsin
Cap	Capacitor
CH	Cinch Manufacturing Co., Chicago, Illinous
IPC	Industrial Products Co.
USECO	U.S. Engineering Co, Glendale, California

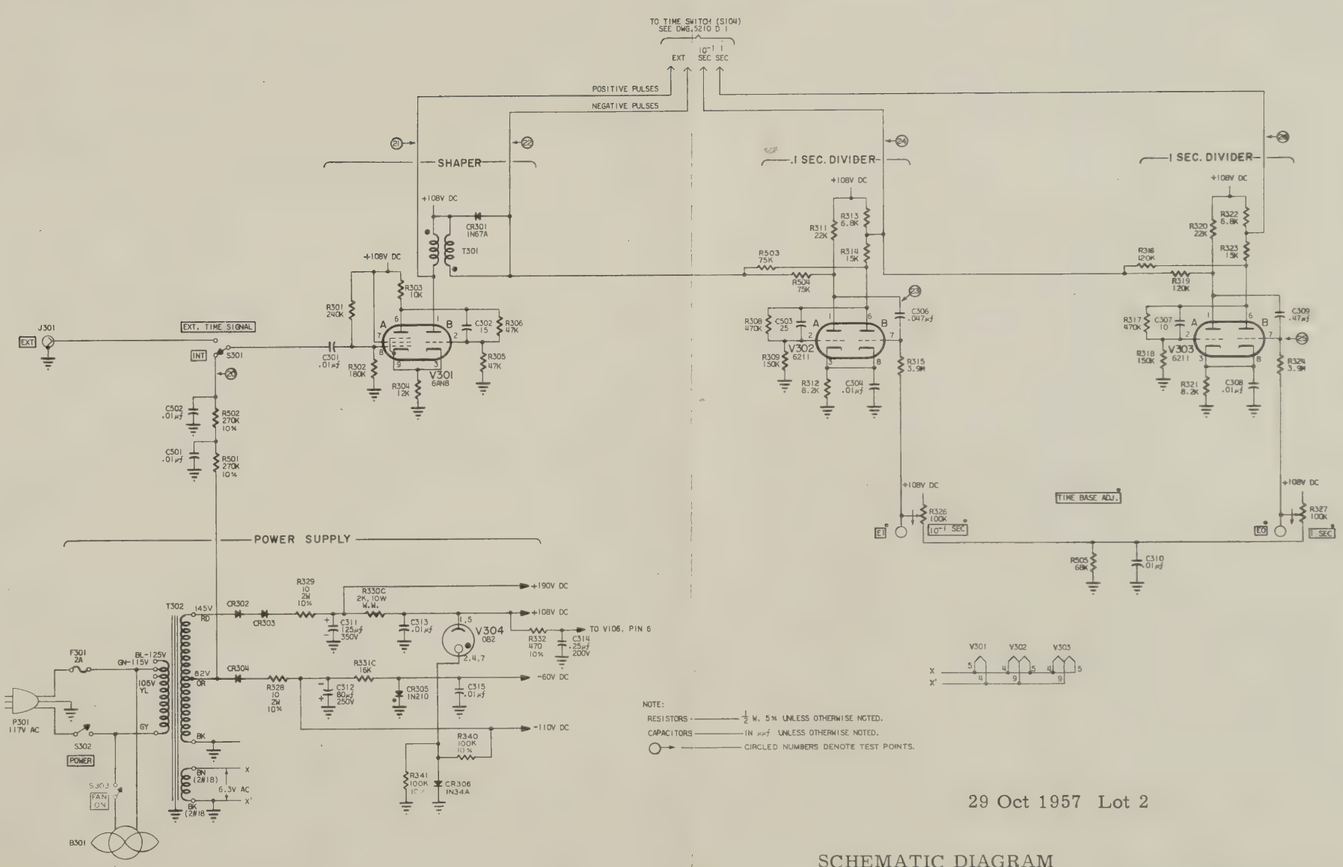
NOTE: Any resistor which does not appear in the list below is a fixed composition resistor of the value, wattage and tolerance noted on the schematic diagram. All other electrical components are listed.

Detail No.	Stock No.	Description	Manufacturer & No.
B301	9-3390	Motor, 115V 60 CPS	General Industries
C301	2-2230	Cap. . 01 μf, Disc. Ceramic	Erie 811
C302	2-2135	Cap. , 15 μμf, 500 V dc Silvered Mica	Sangamo RR 1415
C304	"	Same as C301	
C306	2-5603	Cap. , .047 μf, 300V dc Sub Min Paper	Sprague 186P4 7353S3
C307	2-2082	Cap. , .10 μμf, 500 dc Silvered Mica	Sangamo RR 1410
C308		Same as C301	
C309	2-5604	Cap. , .47 μfd, 300V dc Sub Min Paper	Sprague 186P47453S3
C310		Same as C301	
C311	2-5630	Cap. , 125 μf, 350 V dc Electrolytic	Sangamo PL35125
C312	2-5245	Cap. , 80 μf, 250 V dc Electrolytic	Sangamo PL2580
C313		Same as C301	
C314	2-5747	Cap. , .25 μf, 200 V	Hopkins Eng. P2520
C315		Same as C301	
CR301	8-4184	Diode, 1N67A	
CR302, CR303, CR304.	8-4425	Rectifier, Silicon 130 V RMS 500 MA	Sarkes Tarzian M500
CR305	8-S4369	Diode, 1N210	National Semi Conductor
E301 & E302	17-3284	Jack, Nylon Tip Jack	Johnson 105-602
F301	7-0504A	Fuse. 2 Amp Slo Blo	Littlefuse 313002
J301	17-3179	Connector, Low Voltage	IPC MS595
R315	1-5600	Resistor, 3.9 M, 1/2 W, 5 %	Electra DC 1/2A
R324		Same as R315	
R325	1-1170A	Resistor 33K, 1/2 W. 5 %	

Detail No.	Stock No.	Description	Manufacturer & No.
R326 & R327	1-1340	Potentiometer, 100 K, 2 W,	AB JU 1041
R330C	1-1067	Resistor, 2000Ω, 10W, 10%, WW	
R332	1-0207	Resistor, 470Ω, 1/2 W, 10%	AB EB 4711
S301	12-1641	Switch, SPDT Bat Toggle	CH 8282K13
S302 & S303	12-3548	Switch , SPST Bat Toggle	
T301	6-6779	Transformer, 1:17 MH	Pulse Eng ES6-5
T302	6-S6780	Transformer, Power As per Spec. Dwg.	Electro
V301	5-6072	Tube, 6AN8	
V302 & V303	5-6777	Tube, 6211	
V304	5-0531	Tube, OB2	
XF301	4-3154	Fuse Post, for 1 1/4 x 1/4" Fuses	Buss HKP
XV301, XV302, XV303	4-4435	Socket, 9 Pin Min for Printed Circuit	Elco
XV304	4-084	Socket, 7 Pin W/Tube Shield	Cinch 54B12559
	10-6886	Line Cord	Cornish #3532
	24-1721	Lock, Shaft	USECO 1510
	24-6934	Fuse Clips, Rectifier Double For Mtg. M500	Littlefuse 099063
	34-4459	Fuse Clips, Rectifier Single For Mtg. M500	Littlefuse 099062
	24-4645	Knob, Gray 3/4	Kurz Kasch S-645-1-BB-621-622
	24-4647	Knob, Gray 1 1/4	Kurz Kasch S-648-3-BB-621-622
	24-0492	Tube Shield , 7 Pin Large	Cinch G12564/754
	24-6767	Handle, Black Cowhide W/Spring clips	Specialty Leather #553
	24-5799	Fan Blade, 5 1/2 " Clockwise Rotation	Torrington #0-5525-4

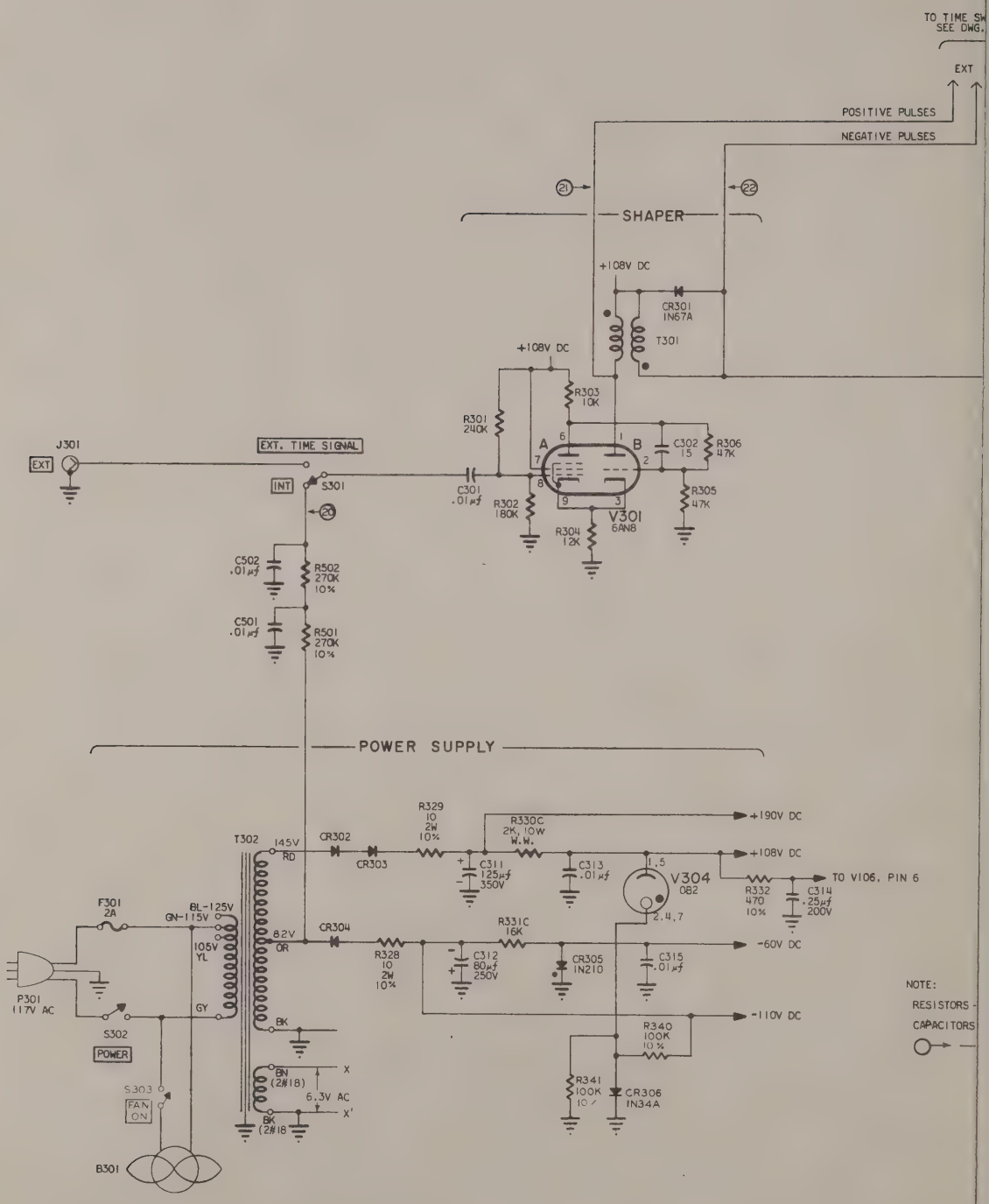
ADDITIONS

C501 & C502		Same as C301	
C503	2-2138	Capacitor, 25 μμf, 500V dc Silvered Mica	Sangamo RR 1425
CR306	8-0668	Diode, 1434A	



29 Oct 1957 Lot 2

SCHEMATIC DIAGRAM
TIME BASE GENERATOR AND POWER SUPPLY
MODEL 5210
DWG. NO. 5210D2


TO TIME SW
SEE DWG.
EXT
POSITIVE PULSES
NEGATIVE PULSES
21
22
SHAPER
+108V DC
CR301
IN67A
T301
+108V DC
R303
10K
R301
240K
A
B
C302
15
R306
47K
J301
EXT
EXT. TIME SIGNAL
INT
S301
C301
.01μf
R302
180K
R305
47K
V301
6AN8
R304
12K
C502
.01μf
R502
270K
10%
C501
.01μf
R501
270K
10%
POWER SUPPLY
R329
10
2W
10%
R330C
2K, 10W
W.W.
+190V DC
+108V DC
T302
145V
RD
CR302
CR303
C311
125μf
350V
C313
.01μf
V304
0B2
R332
470
10%
C314
.25μf
200V
TO V106, PIN 6
F301
2A
BL-125V
GN-115V
105V
YL
82V
OR
CR304
R331C
16K
-60V DC
R328
10
2W
10%
C312
80μf
250V
CR305
IN210
C315
.01μf
P301
117V AC
GY
S302
POWER
BK
R340
100K
10%
-110V DC
R341
100K
10%
CR306
IN34A
BN
(2#18)
6.3V AC
BK
(2#18)
S303
FAN
ON
B301
NOTE:
RESISTORS -
CAPACITORS

INSTRUCTION MANUAL

Models 705AH, 705AJ & 705AK
DECIMAL COUNTING UNITS

Lot No.

BERKELEY division
Beckman Instruments, Inc.

Richmond 4, California
18 March 1957

WARRANTY

Instruments sold by Berkeley Division, Beckman Instruments, Inc., (hereafter called "the Company") are warranted only as stated below.

Subject to the exceptions and upon the conditions specified below, the Company agrees to correct, either by repair, or, at its election, by replacement, any defect of material or workmanship which develops within one year after delivery of the instrument to the original purchaser by the Company or by an authorized representative, provided that investigation and factory inspection by the Company discloses that such defect developed under normal and proper use.

The exceptions and conditions mentioned above are the following:

(a) All instruments claimed defective must be returned to the Company, transportation charges prepaid, and will be returned to the customer with the transportation charges collect.

(b) The Company makes no warranty concerning components or accessories not manufactured by it, such as tubes, fuses, batteries, etc. However, in the event of the failure of any component or accessory not manufactured by the Company, the Company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.

(c) The Company shall be released from all obligations under its warranty in the event repairs or modifications are made by persons other than its own service personnel or authorized representatives' personnel unless such repairs by others are made with the written consent of the Company.

(d) Except as stated above, the Company makes no warranty, express or implied (either in fact or by operation of law), statutory or otherwise; and, except to the extent stated above, the Company shall have no liability under any warranty, express or implied (either in fact or by operation of law), statutory or otherwise.

(e) The Company expressly disclaims any liability to its customers, dealers, and to users of its products, and to any other person or persons for consequential damages of any kind and from any cause whatsoever arising out of or in any way connected with the manufacture, sale, repair, replacement of, or arising out of or in any way connected with the use of any of its products.

(f) Representations and warranties made by any person, including representatives of the Company, which are inconsistent or in conflict with the terms of this warranty (including but not limited to the limitation of the liability of the Company as set forth above) shall not be binding upon the Company unless reduced to writing and approved by an officer of the Company.

(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate. Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, Berkeley division of Beckman Instruments, Inc., Richmond 4, California.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

Berkeley reserves the right to make changes in design at any time without incurring any obligation to modify equipment previously purchased to conform to subsequent design changes.

BERKELEY DIVISION
BECKMAN INSTRUMENTS, INC.

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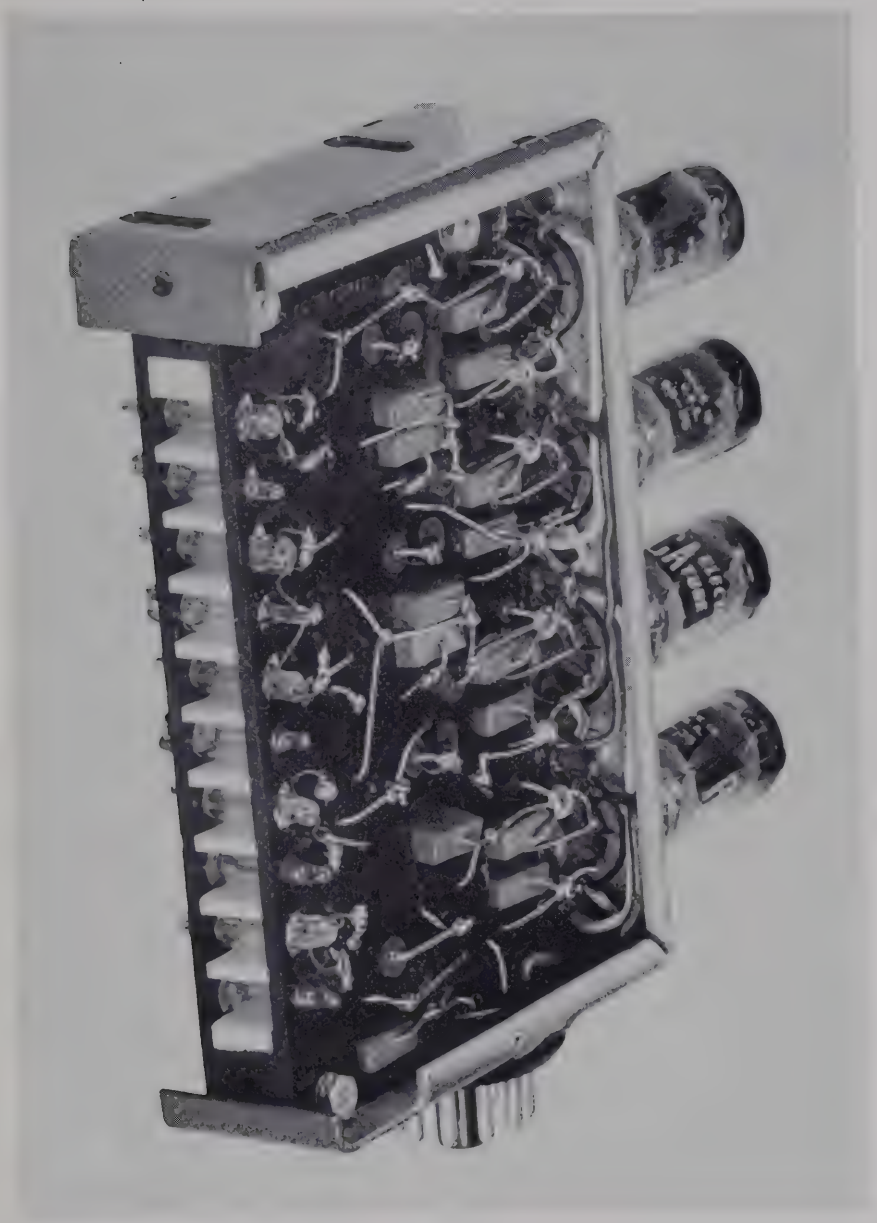

Model 705AH Decimal Counting Unit with side covers and indicating panel removed.

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INTRODUCTION

These decimal counting units are direct-reading, plug-in electronic counters. The number of input pulses received is indicated by the illumination of one of ten neon lamps placed behind a numbered acetate panel. Each unit counts from zero to nine, the tenth pulse resetting the counter to zero and simultaneously generating an output signal. Any number of these units can be connected in cascade (the output of one unit driving the next) forming a counter whose total count capacity depends only on the number of DCU's. Thus, five units will count to 99, 999 resetting to "00, 000" on the 100, 000th pulse.

Models 705AH and 705AK generate a binary coded decimal readout. This code is in the form of high or low voltages at each of four pins on the DCU plug.

SPECIFICATIONS

Count Indication

Direct reading, decimal presentation

Power Requirements

Heaters: 6.3 v. at 1.2 amps

Plates: 300 v. at 13 ma

Input Requirements

Negative pulses (See "OPERATION")

Output Characteristics

Designed to drive a Model 705A DCU or any modification thereof (i.e., 705AH, 705AK, etc.)

Resolution of Paired Pulses

5 microseconds

Reset

Will reset to either zero or nine depending on polarity of reset pulse applied.

Maximum Counting Rate

100, 000 counts per second

Construction

Plug-in unit, 11-pin socket

OPERATION

Power Requirements. The heaters require 6.3 volts ac at 1.2 amperes. The plate circuits may be operated on from 200 to 400 volts, although the design center is 300 volts at 13 ma. Plate voltage may be applied in the form of B + and B - voltages. The d-c level of all output voltages will depend upon the level of the plate supply voltages.

Input Requirements. A negative pulse at least two microseconds wide is required to drive the unit. The optimum pulse amplitude depends on the rise time. With a rise time of 0.5 microseconds (measured between ten and ninety percent values) the pulse amplitude should be between 75 and 135 volts. With a two-microsecond rise time, the amplitude should be between 120 and 165 volts. When operating the plate circuits on 300 volts, optimum performance is obtained with a rise time of one microsecond or less and a pulse amplitude of 100 volts. If the unit is powered by unregulated d-c supplies, the input pulse amplitude should vary in phase with the supply voltage. The input load presented when an input pulse occurs is 15K ohms in series with 100 micromicrofarads.

Output Characteristics. The output is the rectangular waveform shown in Figure 3. As every tenth input pulse triggers the unit from count display "9" to count display "0", a negative transient occurs at pin 4 of the DCU plug. With a plate supply of 300 volts, the potential at pin 4 drops from + 135 to + 55 volts with respect to B-. This transient can be used to drive succeeding decimal counting units or other circuitry. The load impedance connected

between the output terminal and ground must not be less than 300K or 6K in series with 100 micro-microfarads.

Method of Resetting after a Counting Period. A DCU can be reset to a registered count of either zero or nine by the application of a voltage pulse of the proper polarity to the proper pin of the DCU plug. See the table below.

	RESET TO ZERO		RESET TO NINE	
	Pulse Polarity	Applied at Pin No.	Pulse Polarity	Applied at Pin No.
705AH	Neg.	8	Pos.	8
705AJ	Neg.	8	Pos.	8
	Pos.	3	Neg.	3
705AK	Neg.	8	Pos.	8

The reset pin (or pins in the base of Model 705AJ) should be maintained at the B- supply voltage except when a reset pulse occurs. A 50-volt pulse at least 3μseconds wide is adequate. A 100-volt pulse need be only 1.5μseconds wide. There is no maximum pulse width; however the DCU will not begin counting again until the reset pin returns to the B- supply voltage.

Simply disconnecting a reset pin from B- with a switch or relay will have the same effect as applying a positive pulse.

Binary Code Readout. Models 705AH and 705AK generate a modified binary code representing the decimal digit registered. The code appears in the form of a voltage (high or low) at one plate of each of four double-triode binaries. In the table below, "0" represents a plate voltage of approximately+55 volts with respect to B-; "1" represents a plate voltage of about+135 volts with respect to B-. (These are the voltage levels which appear when using a 300-volt plate supply.) Each of the four plates is coupled to a pin of the DCU plug through a 1.2 megohm resistor except in the case of pin 4 on the 705AK DCU. This pin is connected directly to a plate of the fourth binary. To obtain a readout voltage at this pin, it is necessary to add a 1.2M resistor externally.

DECIMAL DIGIT REGISTERED	FOUR - LINE BINARY CODE			
	1st Binary Stage (Pin 2 of DCU plug)	2nd Binary Stage (pin 6 of DCU plug)	3rd Binary Stage (Pin 9 of DCU plug)	4th Binary (Pin 10, 705AH) (Pin 4, 705AK)
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	1	1	0
5	1	1	1	0
6	0	0	1	1
7	1	0	1	1
8	0	1	1	1
9	1	1	1	1

Extinguishing the Indicating Lamps During the Counting Period. On Models 705AJ and 705AK, it is possible to prevent the neon bulbs from lighting by placing approximately -100 volts with respect to B- on pin 10 of the DCU plug. Ordinarily, the user will wish to extinguish the bulb while the DCU is actively counting, and to allow them to light, indicating the registered count at the end of a counting period.

CIRCUIT DESCRIPTION

The Binaries. The decimal counting units contain four "flip-flop" circuits. These circuits are slightly modified versions of the Eccles-Jordan trigger circuit. They are referred to here as binaries.

Figure 1 is a schematic diagram of a typical binary. It consists of two triode voltage amplifiers with the plate of each direct-coupled to the grid of the other. With no input this circuit assumes one of two stable states: V1 conducting steadily and V2 cut

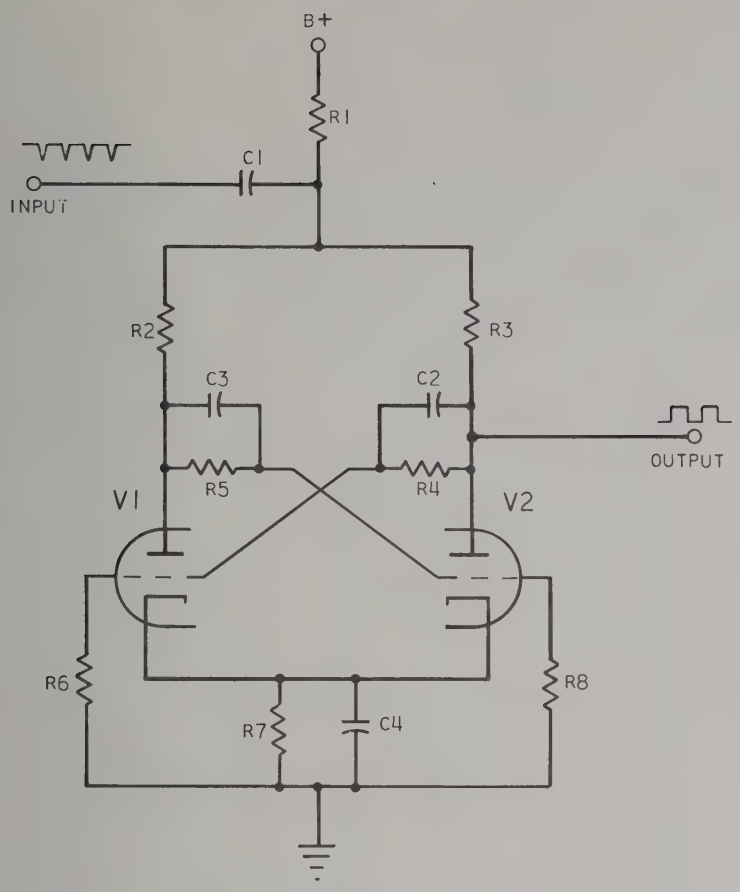


FIGURE 1. A TYPICAL BINARY.

off, or V2 conducting and V1 cut off. Suppose V1 is not conducting. Then, its plate is near the B- voltage. A portion of this voltage, applied to the grid of V2 through the voltage dividing network R5 and R8, raises this grid above cut-off and permits V2 to conduct. While V2 is conducting, the low positive potential at its plate, coupled to the grid of V1 through the dividing network R4 and R6, holds this grid several volts below cut-off. Since small changes in the potential at the grid of V1 will not raise it above cut-off, this state is stable and will persist until disturbed by an appreciable input signal. Notice that, since the circuit is symmetrical, the opposite state is equally stable.

The circuit is triggered from one state to another by negative pulses applied at the input. For example, assume that V2 is conducting and V1 is cut off. If a negative pulse is applied to the input, there is a drop in the plate voltage of V1. This drop in voltage is transmitted through a crossover network (R5, R8, C3 and the grid-to-ground capacitance of V2) and applied to the grid of V2. The plate voltage of V2 then starts to rise, carrying with it the grid of V1. If the input pulse is of sufficient amplitude, V1 begins to conduct. The moment V1 conducts, the drop in voltage at its plate, coupled to the grid of V1, reinforces the negative transient there. This regenerative action proceeds rapidly until V2 is cut off and V1 is conducting at a steady rate. The next adequate input transient causes a reverse action and returns the binary to its original state. Thus, the binary completes a cycle for every two input transients applied, making it a scale-of-two. The output is the drop in voltage at one of the plates as that triode begins to conduct. This output, consisting of one negative transient for every two input transients, is suitable for driving another binary. By connecting binaries in cascade (output of one to input of the next) a counter having a scale of any power of two can be built.

The Scale of Ten. In the Model 705A four binaries are connected in cascade forming a scale-of-16 which is permuted to a scale-of-10 by two positive feedback paths. (See Figures 2 and 3) For the first three negative input pulses, the unit operates like a simple binary counter. At the fourth input pulse, the third binary is triggered for the first time, sending a pulse through the first feedback path which triggers the second binary. Since it requires two input pulses to trigger the second binary, this is equivalent to adding two input pulses; therefore, the state of the unit now

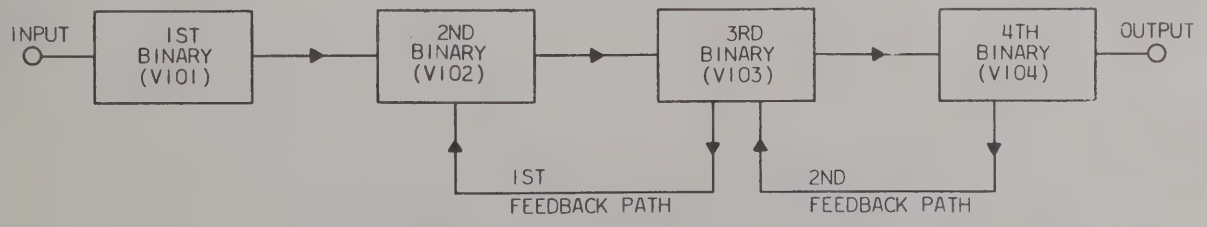


FIGURE 2. BLOCK DIAGRAM.

corresponds to a binary count of six. The sixth input pulse (equivalent to the eight in a simple binary chain) triggers the fourth binary which sends a pulse through the second feedback path, triggering the third binary. This is equivalent to adding four more input pulses so the state of the unit now corresponds to a binary count of 12. For the next four input pulses (7 thru 10) the unit operates again as a simple binary chain, producing an output pulse at the tenth input pulse. Adding the equivalent of six input pulses internally has changed the binary chain from a scale-of-16 to a scale-of-10.

When the third binary is triggered by a feedback pulse, it tends to retrigger the second binary in the same way that it did at the time of input pulse four. This tendency is offset by a simultaneous opposing signal from the fourth binary.

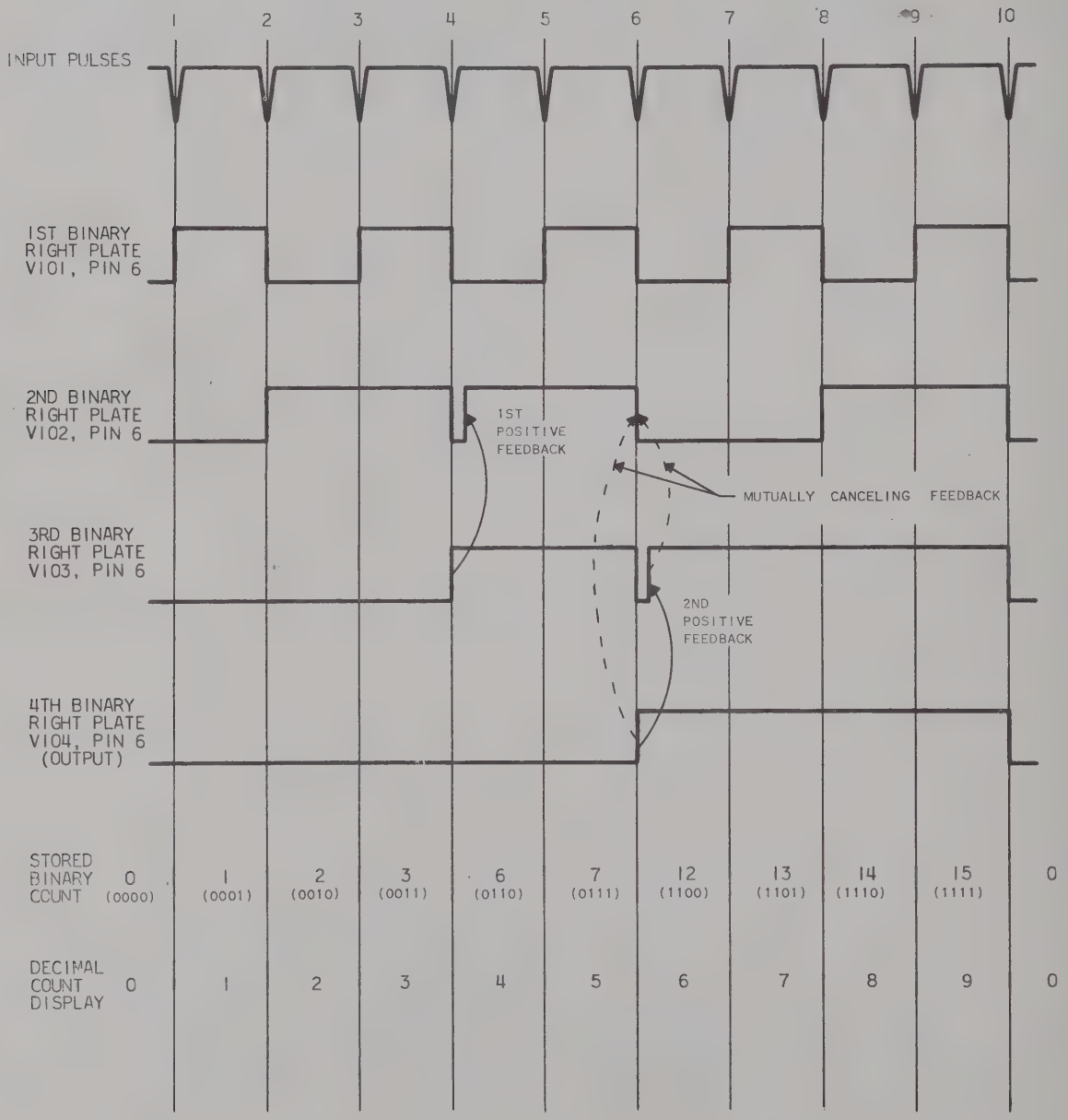


FIGURE 3. IDEALIZED WAVEFORMS. "RIGHT PLATE" REFERS TO THE PLATE APPEARING ON THE RIGHT-HAND SIDE OF THE BINARY AS DRAWN ON THE SCHEMATIC.

TROUBLESHOOTING PROCEDURES

When a decimal counting unit is suspected of counting incorrectly, it should be interchanged with another unit in the instrument or replaced with a spare unit to determine whether the trouble is in the suspected unit or in the associated circuitry. This test should be made very carefully. Because the counting unit is usually the indicating device of an instrument, it is often accused of operating incorrectly when the fault is external to it.

Two methods are recommended for locating a defect in a DCU. The first is to observe the lighting sequence while driving the unit at a slow pulse rate. The second is to study the output waveform of each binary while driving the unit fast enough to create an oscilloscope display. It is impossible to say which method should be used in every case, since marginal failures may occur at high counting speeds and not at lower counting rates, and vice versa. The first method is the only way that a neon lamp failure can be located, and it can be used to locate component and tube failures. For this reason, it is recommended that this method be used first. The table of common troubles lists the probable defects indicated by particular variations from the proper lighting sequence. Binary output waveforms may be compared with the idealized waveforms of Figure 3 and the photographs appearing in Figure 4 & 5.

A table of typical voltages and resistances has been provided to help the serviceman locate a defect within one of the binary stages. Values may deviate considerably from those given without causing trouble. The fact that the unit is designed to operate at plate supply voltages ranging from 200 to 400 volts is a rough indication of permissable tolerances.

TROUBLESHOOTING CHART

NOTE: Reset unit to zero before testing for symptoms

SYMPTOMS	POSSIBLE CAUSES
Unit Fails to Count	(a) Insufficient supply voltage. (b) Input signal of insufficient amplitude (c) Input signal of wrong polarity. (d) First stage inoperative.
Unit Counts Spuriously	(a) Extraneous input signals. (b) Pulses received through power supply. (c) External voltages picked up by output lead.
Units Counts Erratically	(a) Input signal too large or small, incorrect rise time. (b) Supply voltage fluctuating too much.
Unit Fails to Reset	(a) Stray counts from reset switch or associated circuitry. (b) Defective component.

Units counts regularly but neon bulbs light in wrong sequence and the pattern of lighting is repeated consistently after a definite number of input pulses. One or more bulbs may be lit simultaneously during a cycle but the number of states per cycle remains constant.

1.	Units skips every other number	(a) First stage defective. (b) Input circuit supplies double pulses.
2.	Two stable states per cycle.	(a) Second stage defective(Display sequence may be 01 or 45). (b) Loss of drive to second stage (01).
3.	Four stable states per cycle.	(a) Third stage defective (Display sequence may be 0123 or 6789). (b) Loss of drive to third stage (0123).
4.	Six stable states per cycle.	(a) Output excessively loaded (Display sequence may be 012345). (b) Last stage inoperative (Display sequence may be 012345 or $67^{89}_{23}89$* (c) Loss of drive to fourth stage (Display sequence may be 012345).
5.	Eight stable states per cycle or any failure where two successive numbers are skipped.	(a) Second or third stage failure.
6.	Ten stable states per cycle, but the lighting sequence is incorrect.	(a) When the wrong neon lamp lights, the trouble is usually a defect in the lamp that should have lit, but it may be a defect in the lamp that lit improperly. It's also possible that more than one lamp will light in place of the correct one.
7.	Twelve stable states per cycle.	(a) When lighting sequence is $0123^{01}_{45}456789$* the cause may be a failure of the first feedback or lowered cathode emission in first or second binary. (b) When the lighting sequence is $01234567^{23}_{89}89$ the cause may be failure of the second feedback or low cathode emission in third or fourth binary.

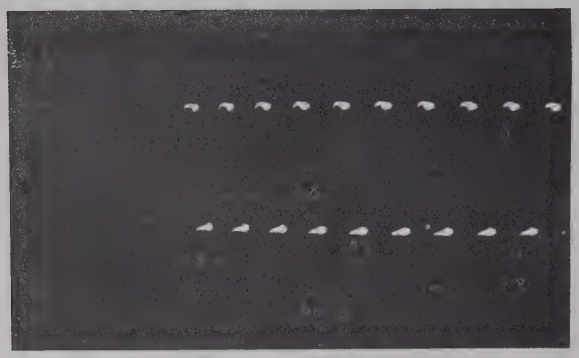
* One digit above another means both lamps are lit.

TABLE OF VOLTAGES & RESISTANCES

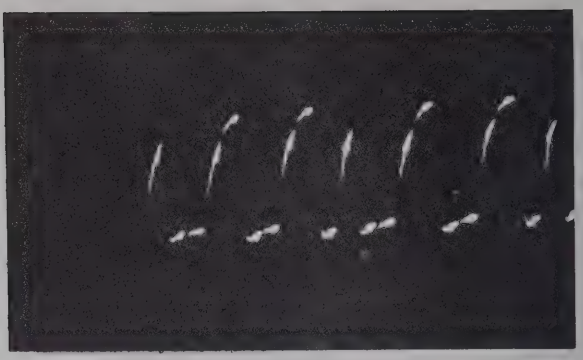
Tube	Pin No.	D.-C. Voltage with respect to B-.*	Resistance to B minus Terminal**
V101	1	170	105K
	2	17	85K
	3, 8	37	12K
	4, 5, 9	Filaments	
	6	60	105K
	7	37	85K
V102	1	135	93K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	93K
	7	30	83K
V103	1	135	100K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	100K
	7	30	83K
V104	1	135	93K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	93K
	7	30	83K

* Voltages measured in unit with 300-volt plate supply

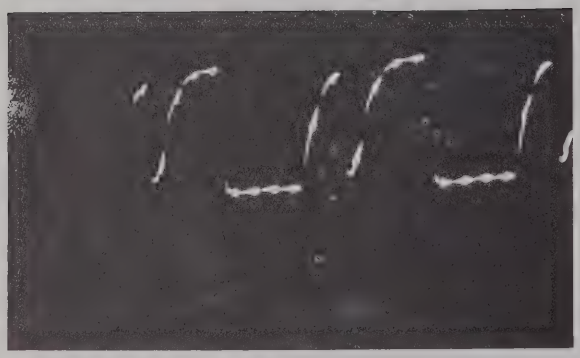
** Before making resistance measurements jumper pins 3 and 8 on the DCU plug.



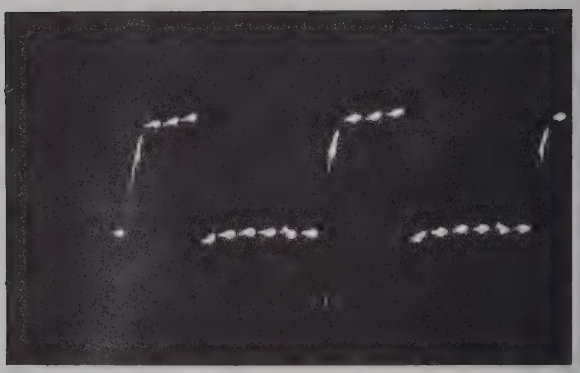
(1) First Binary Output (V101, Pin 6).
Upper voltage level is +168v
Lower voltage level is +55v



(2) Second Binary Output (V102, Pin 6)
Upper voltage level is +140v
Lower voltage level is +55v.

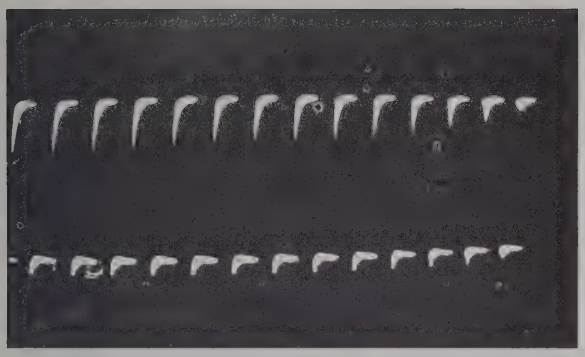


(3) Third Binary Output (V103, Pin 6)
Upper voltage level is +140v.
Lower voltage level is +55v.

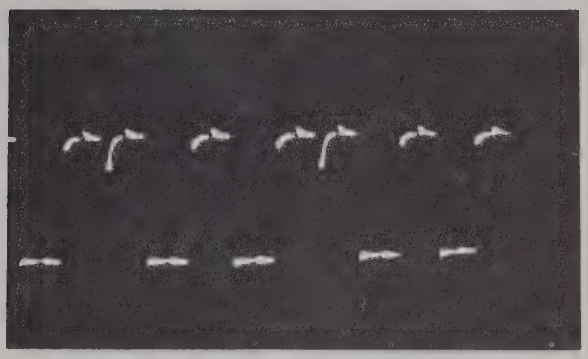


(4) Fourth Binary Output (V104, Pin 6).
Upper voltage level is +140v.
Lower voltage level is +55v.

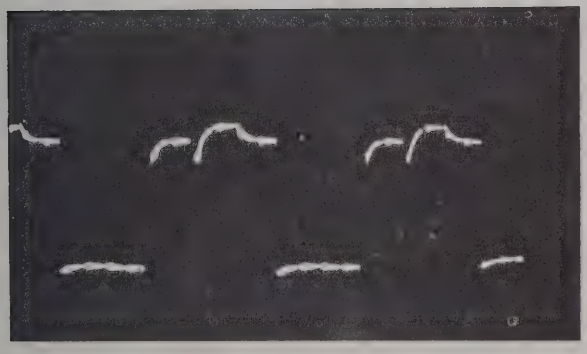
FIGURE 4. BLANKED WAVEFORMS AT INPUT FREQUENCY OF 20KC. ALL VOLTAGE LEVELS ARE MEASURED WITH RESPECT TO B MINUS.



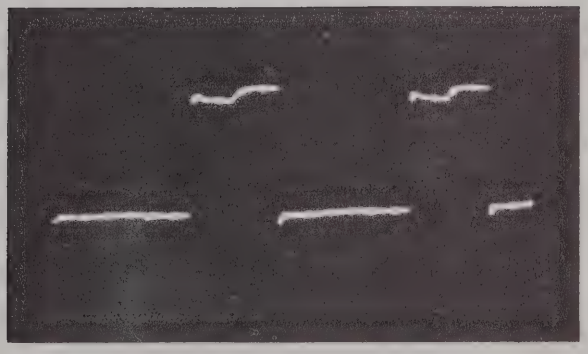
(1) First Binary Output (V101, Pin 6).
Upper Voltage level is +168V
Lower voltage level is +55v



(2) Second Binary Output (V102, Pin 6)
Upper voltage level is +140v
Lower voltage level is +55v.



(3) Third Binary Output (V103, Pin 6)
Upper voltage level is +140v.
Lower voltage level is +55v



(4) Fourth Binary Output (V104, Pin 6).
Upper voltage level is +140v.
Lower voltage level is +55v.

FIGURE 5. BLANKED WAVEFORMS AT INPUT FREQUENCY OF 100KC. ALL VOLTAGE LEVELS ARE MEASURED WITH RESPECT TO B MINUS.

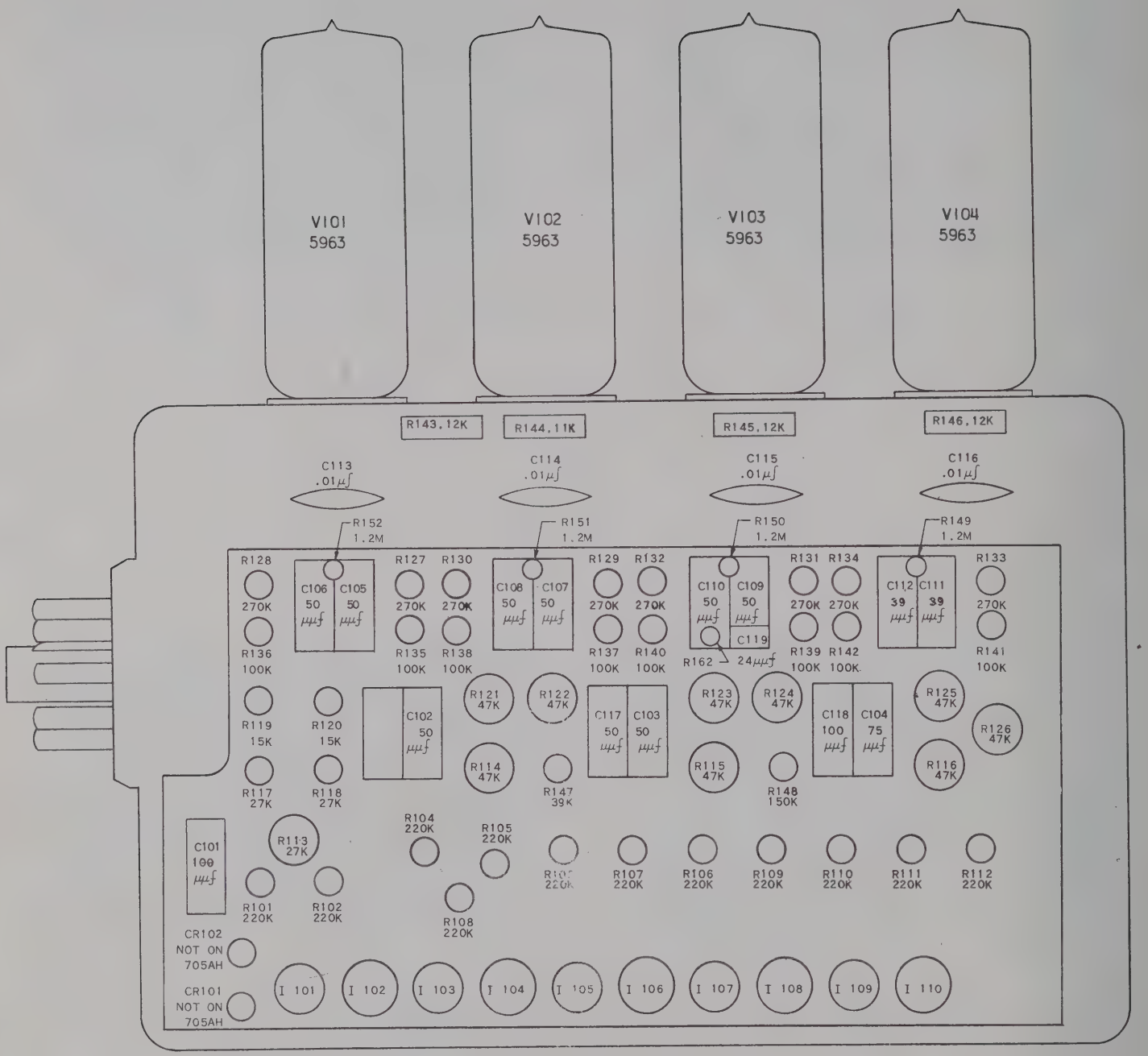
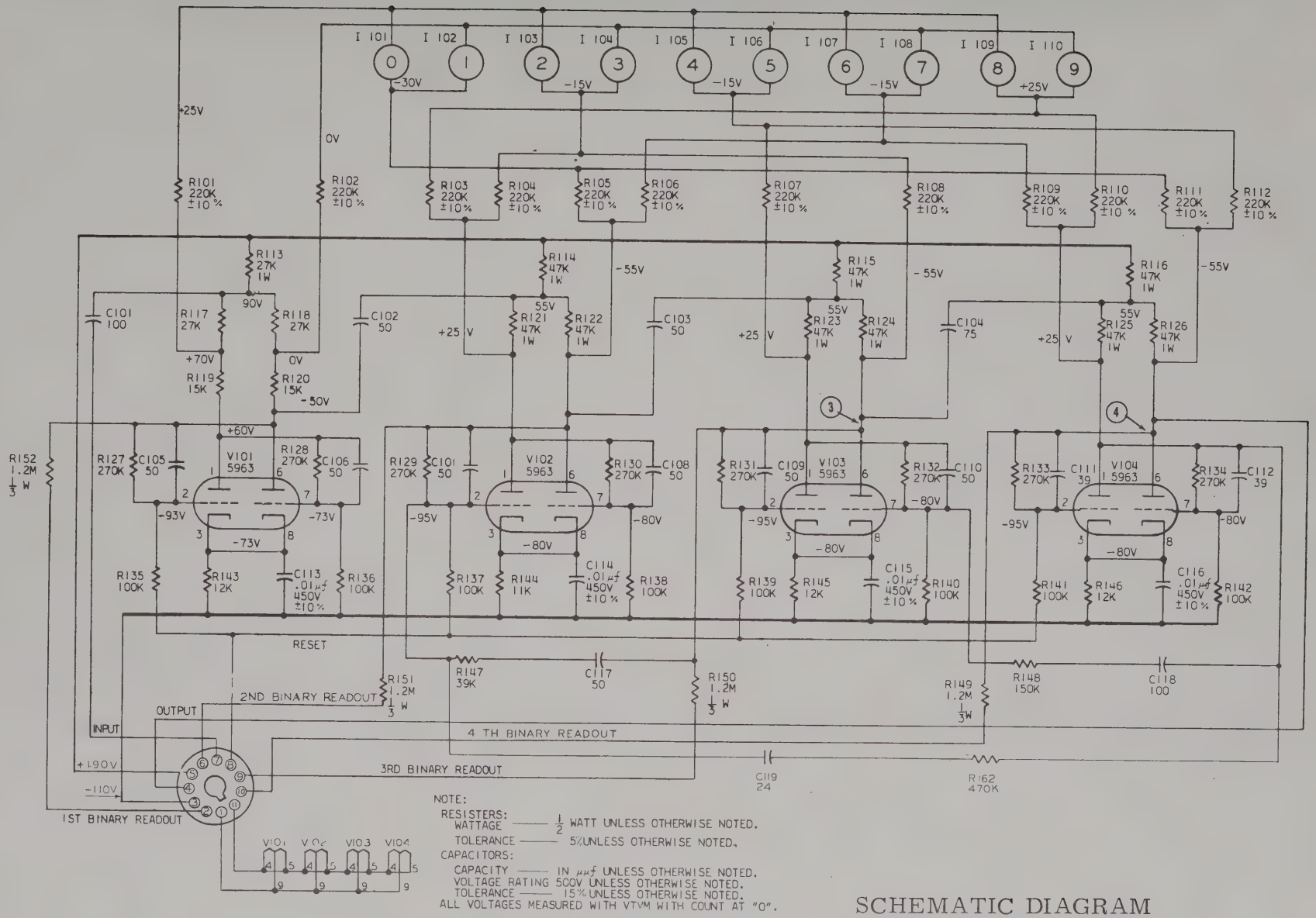
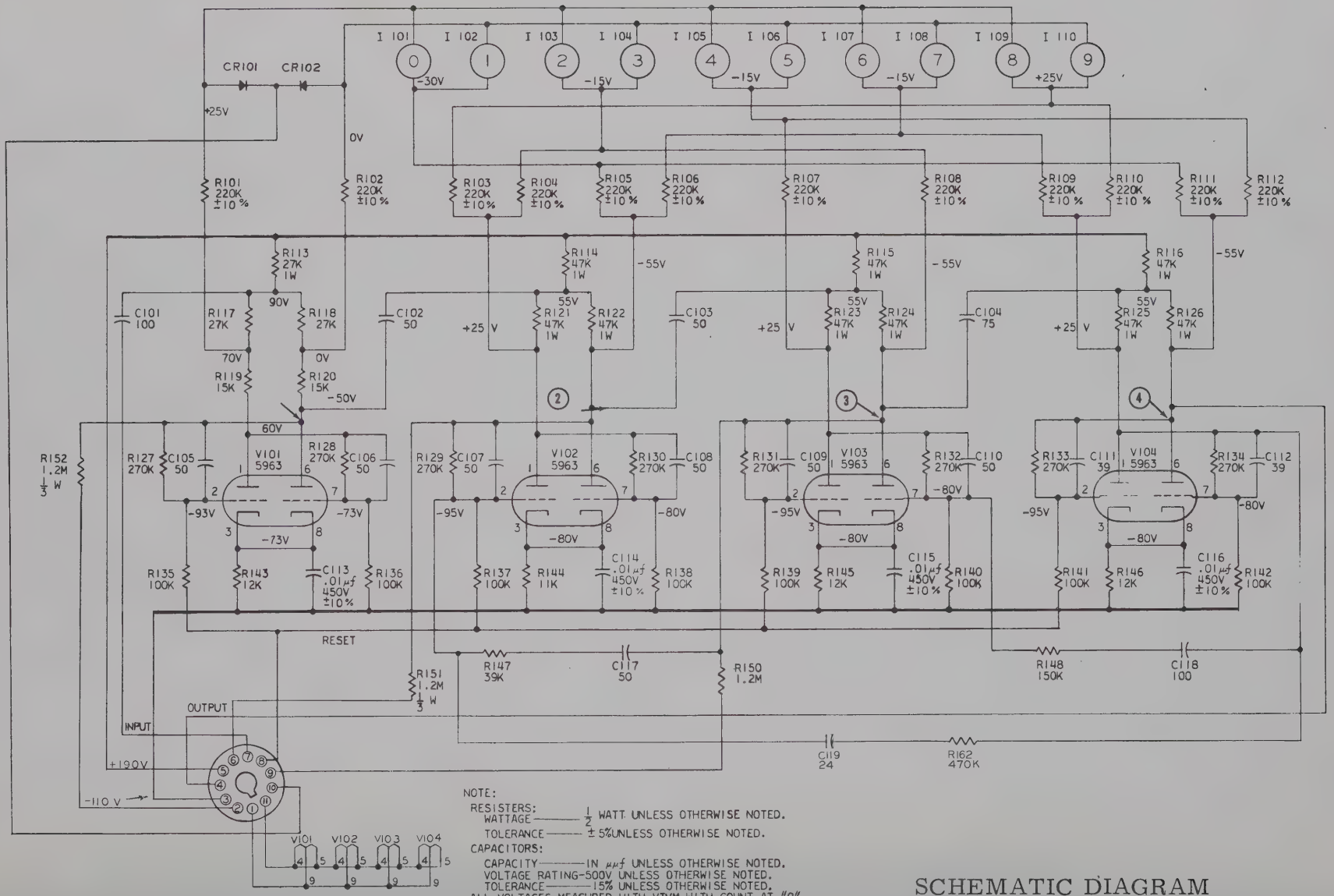


FIGURE 6. PARTS LOCATION



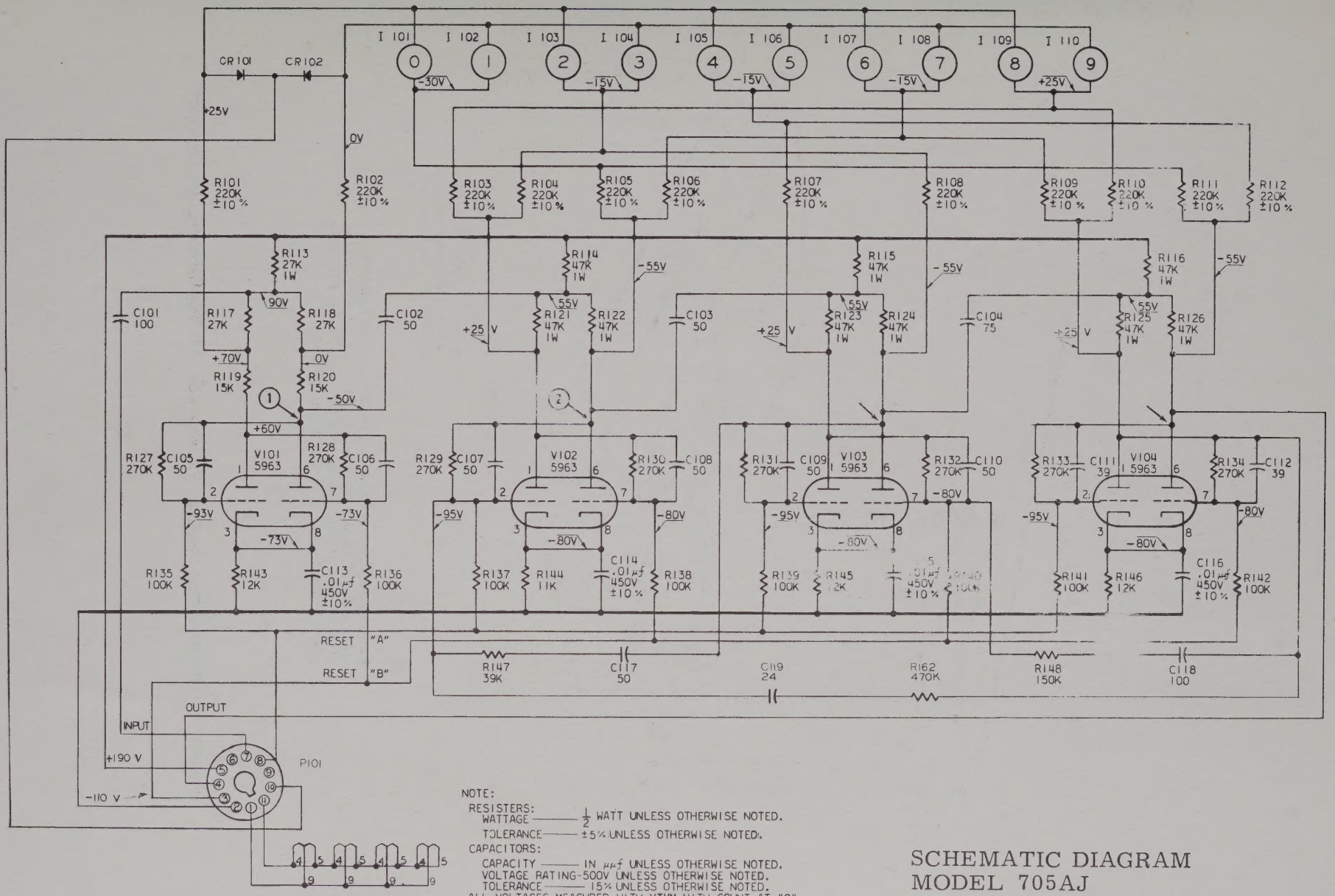
NOTE:
RESISTERS:
WATTAGE —— $\frac{1}{2}$ WATT UNLESS OTHERWISE NOTED.
TOLERANCE —— 5% UNLESS OTHERWISE NOTED.
CAPACITORS:
CAPACITY —— IN μμf UNLESS OTHERWISE NOTED.
VOLTAGE RATING 500V UNLESS OTHERWISE NOTED.
TOLERANCE —— 15% UNLESS OTHERWISE NOTED.
ALL VOLTAGES MEASURED WITH VTVM WITH COUNT AT "0".

SCHEMATIC DIAGRAM
MODEL 705AH
DECIMAL COUNTING UNIT



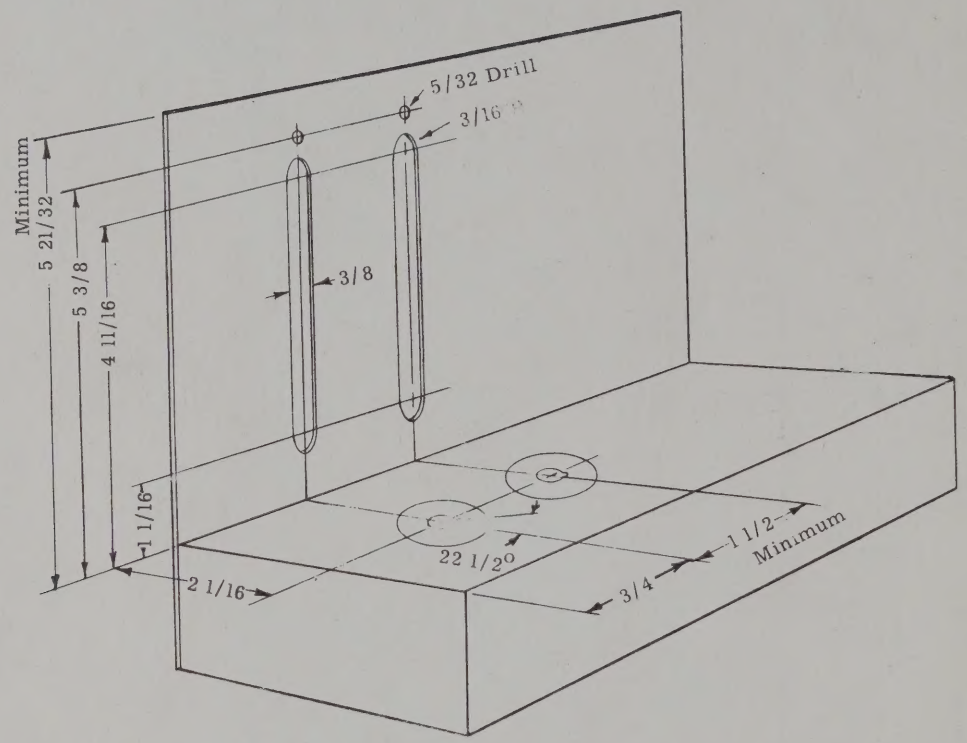
NOTE:
RESISTERS:
WATTAGE——— $\frac{1}{2}$ WATT UNLESS OTHERWISE NOTED.
TOLERANCE——— ± 5% UNLESS OTHERWISE NOTED.
CAPACITORS:
CAPACITY——— IN μμf UNLESS OTHERWISE NOTED.
VOLTAGE RATING-500V UNLESS OTHERWISE NOTED.
TOLERANCE——— 15% UNLESS OTHERWISE NOTED.
ALL VOLTAGES MEASURED WITH VTVM WITH COUNT AT "0".

SCHEMATIC DIAGRAM
MODEL 705AK
DECIMAL COUNTING UNIT



NOTE:
RESISTERS:
WATTAGE ——— $\frac{1}{2}$ WATT UNLESS OTHERWISE NOTED.
TOLERANCE ——— ±5% UNLESS OTHERWISE NOTED.
CAPACITORS:
CAPACITY ——— IN μμf UNLESS OTHERWISE NOTED.
VOLTAGE RATING-500V UNLESS OTHERWISE NOTED.
TOLERANCE ——— 15% UNLESS OTHERWISE NOTED.
ALL VOLTAGES MEASURED WITH VTVM WITH COUNT AT "0".
AND PIN #10 DISCONNECTED.

SCHEMATIC DIAGRAM
MODEL 705AJ
DECIMAL COUNTING UNIT



NOTE: Dimensions are based on the use of an Amphenol "MIP" 8 or 11-pin socket mounted above the chassis.

The drawing shows chassis dimensions for mounting two Model 705A DCU's side by side. All modifications of the Model 705A (705AH, 705AF, etc.) have precisely the same dimensions as the standard 705A.

Mounting Dimensions, Model 705A and All Modifications Thereof